KEMENTERIAN PENDIDIKAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA
SULTAN SALAHUDDIN ABDUL AZIZ SHAH

5TH. NATIONAL CONFERENCE ON TVET FOR UNDERGRADUATE STUDENTS NCTS2025

NCTS
National Conference on TVET for Undergraduate Students

e-PROCEEDING

"The Future in Our Hands :
Empowering Youth for Technological and Social Advancement"

24 & 25 JUN 2025

Politeknik Sultan Salahuddin Abdul Aziz Shah

Anjuran :
Pusat Penyelidikan dan Inovasi (PPI),
Jabatan Pendidikan Politeknik & Kolej Komuniti (JPPKK)
& Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA)

Bersama :
Politeknik Ungku Omar (PUO),
Politeknik Ibrahim Sultan (PIS) &
Politeknik Sultan Azlan Shah (PSAS)

TVET MALAYSIA
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MALAYSIA MADANI

e- PROCEEDING

5TH NATIONAL CONFERENCE ON TVET FOR UNDERGRADUATE STUDENTS (NCTS 2025)

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PRAKATA

National Conference On TVET Undergraduate Students (NCTS) merupakan persidangan tahunan pelajar ijazah Sarjana Muda politeknik yang dianjurkan oleh Pusat Penyelidikan & Inovasi (PPI), Jabatan Pendidikan Politeknik dan Kolej Komuniti (JPPKK) sejak tahun 2020 dengan kerjasama EMPAT (4) politeknik di Malaysia yang menawarkan program ijazah Sarjana Muda iaitu Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), Politeknik Ungku Omar (PUO), Politeknik Ibrahim Sultan (PIS) dan Politeknik Sultan Azlan Shah (PSAS). Pada tahun ini, PSA telah dilantik sebagai tuan rumah bagi NCTS 2025.

Tujuan utama persidangan ini diadakan adalah bagi mengetengahkan hasil penyelidikan dan inovasi di kalangan para pelajar ijazah Sarjana Muda politeknik dari pelbagai disiplin ilmu, di peringkat kebangsaan. Terdapat TUJUH (7) program ijazah Sarjana Muda di Politeknik Malaysia iaitu:

Sarjana Muda Teknologi Kejuruteraan Awam (BCT) di PUO
Sarjana Muda Teknologi Kejuruteraan Pembuatan (Pengurusan Rangkaian Bekalan) dengan Kepujian (BMS) di PUO
Sarjana Muda Teknologi Kejuruteraan Elektronik Perubatan dengan Kepujian (BEU) di PSA
Sarjana Muda Teknologi Pengurusan Fasiliti dengan Kepujian (BFM) di PSA
Sarjana Muda Sains (Kepujian) Pengurusan Pelancongan & Hospitaliti (BTH) di PIS
Sarjana Muda (Kepujian) Reka Bentuk Komunikasi Visual & Media Baharu (BVC) di PIS
Sarjana Muda Teknologi Kejuruteraan Pembuatan (Reka Bentuk Automotif) (BMA) di PSAS

NCTS memberi peluang kepada para pelajar menterjemahkan hasil projek/penyelidikan mereka ke dalam bentuk penulisan ilmiah dan seterusnya membentangkan kertas penyelidikan mereka. Persidangan ini diharapkan dapat meningkatkan komunikasi serta keyakinan pelajar semasa membentang di khalayak yang lebih luas. Selain itu liputan NCTS 2025 diharapkan akan meningkatkan reputasi Politeknik Malaysia sebagai pusat kecemerlangan TVET, menarik lebih ramai pelajar prospektif melanjutkan pengajian di peringkat sarjana muda di politeknik dan menggalakkan pihak industri untuk bekerjasama dengan pihak politeknik. Natijahnya, NCTS 2025 berpotensi memupuk modal insan yang berkemahiran tinggi dan inovatif, selaras dengan keperluan industri dan pembangunan negara.

KATA ALU-ALUAN

KETUA PENGARAH
PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI
KEMENTERIAN PENDIDIKAN TINGGI

Assalamualaikum warahmatullahi wabarakatuh dan salam sejahtera.

Alhamdulillah, segala puji dan syukur ke hadrat Ilahi kerana dengan limpah rahmat-Nya, *National Conference on TVET for Undergraduate Students (NCTS) 2025* berjaya dianjurkan dengan penuh meriah dan bermakna. Persidangan tahunan ini bukan sahaja menjadi pentas ilmiah untuk pelajar-pelajar TVET memperkasa hasil penyelidikan dan inovasi, bahkan menjadi bukti nyata kepada kekuatan pendidikan politeknik dan kolej komuniti dalam mendepani cabaran masa depan. Saya ingin merakamkan ucapan setinggi-tinggi penghargaan kepada Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA) atas penganjuran yang cemerlang serta kepada semua jawatankuasa, institusi terlibat, rakan industri, pensyarah pembimbing dan pelajar yang telah bersama-sama menjayakan NCTS 2025.

Komitmen dan kesungguhan anda semua mencerminkan iltizam yang kukuh terhadap kecemerlangan TVET negara. Tema tahun ini, *"The Future in Our Hands: Empowering Youth for Technological and Social Advancement"* membawa mesej yang mendalam tentang tanggungjawab kita dalam memperkasakan generasi muda sebagai pemimpin teknologi dan agen perubahan sosial. Dalam dunia yang semakin kompleks dan berasaskan teknologi tinggi, pelajar TVET mesti bersedia bukan sahaja dari aspek teknikal, malah juga dari sudut kepimpinan, pemikiran kritis, dan empati sosial.

NCTS bukan sekadar medan pertandingan atau pembentangan akademik – ia adalah cerminan falsafah pendidikan politeknik dan kolej komuniti yang mementingkan keseimbangan antara kemahiran, nilai dan semangat kebangsaan. Kita ingin melahirkan graduan yang bukan sahaja mahir dalam bidang masing-masing, tetapi juga mampu mencipta peluang, membina jaringan dan menyumbang kepada pembangunan masyarakat secara holistik.

Saya percaya bahawa platform seperti ini berperanan penting dalam mencetus minat pelajar terhadap penyelidikan dan inovasi, memperkukuh kerjasama dengan industri, serta merapatkan jurang antara teori dan aplikasi. Ia juga menggalakkan pemikiran reflektif dan pendedahan kepada pelbagai pendekatan penyelesaian masalah yang diperlukan dalam dunia kerja sebenar. Sebagai Ketua Pengarah, saya menyokong usaha penganjuran NCTS untuk terus mempergiatkan usaha memperkasa ekosistem penyelidikan dan inovasi.

Marilah kita bersama-sama menyokong inisiatif seperti NCTS sebagai sebahagian daripada agenda pembangunan modal insan yang progresif, lestari dan beraspirasi masa depan negara. Alhamdulillah syabas kepada semua yang terlibat dalam penganjuran ini dan diharap usaha murni ini terus memberikan impak lebih jauh dalam bidang penyelidikan dan penghasilan inovasi yang memberi nilai.

Sekian, terima kasih.

YBHG. DATO' DR. HAJI MOHD ZAHARI BIN ISMAIL
Ketua Pengarah
Pendidikan Politeknik dan Kolej Komuniti
Kementerian Pendidikan Tinggi

KATA ALU-ALUAN

PENGARAH
PUSAT PENYELIDIKAN DAN INOVASI (PPI)
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

Assalamualaikum warahmatullahi wabarakatuh dan Salam Malaysia MADANI.

Segala puji dan syukur ke hadrat Allah S.W.T kerana dengan limpah kurnia-Nya, *5th National Conference on TVET for Undergraduate Students (NCTS) 2025* dapat dilaksanakan dengan jayanya.

Tema *"The Future in Our Hands: Empowering Youth for Technological and Social Advancement"* dipilih bagi menggambarkan NCTS sebagai medan yang signifikan dalam membudayakan inovasi, membina jaringan strategik dan menggalakkan penyelesaian kreatif terhadap pelbagai cabaran semasa. Tema ini menggambarkan keyakinan kami terhadap potensi pelajar Sarjana Muda politeknik sebagai pemangkin teknologi dan ejen perubahan sosial dalam membina masa depan negara yang lebih lestari.

Sepanjang penganjuran NCTS, kita telah menyaksikan pelbagai hasil ciptaan yang berimpak tinggi seperti sistem pengurusan tenaga pintar, inovasi pertanian pintar berasaskan IoT, dan sistem keselamatan automatik. Semua ini membuktikan bahawa pelajar Sarjana Muda politeknik bukan hanya memiliki kemahiran teknikal, malah berupaya menghasilkan penyelesaian praktikal yang memberi manfaat kepada komuniti dan industri.

Pusat Penyelidikan dan Inovasi (PPI), JPPKK terus komited dalam memperkukuh ekosistem penyelidikan, inovasi dan pengkomersialan di politeknik dan kolej komuniti melalui dasar yang progresif, bimbingan penyelidikan serta jaringan kerjasama industri yang mampan. Program seperti NCTS adalah antara inisiatif penting dalam melahirkan pelajar Sarjana Muda politeknik yang bukan sahaja kompeten, malah berwawasan dan berdaya saing.

Akhir kata, saya mengucapkan tahniah kepada semua peserta, pensyarah pembimbing, panel juri, rakan industri dan penganjur atas usaha cemerlang dalam menjayakan NCTS 2025. Semoga penganjuran ini menjadi pemangkin kepada lebih banyak penemuan dan inovasi baharu yang mampu memberi sumbangan bermakna kepada pembangunan negara. Teruskan melangkah ke hadapan dengan penuh keyakinan dan iltizam yang tinggi.

YBRS. DR. NORIAH BINTI ABDUL MALEK
Pengarah
Pusat Penyelidikan dan Inovasi (PPI)
Jabatan Pendidikan Politeknik dan Kolej Komuniti

KATA ALU-ALUAN

PENGARAH
POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

Assalamualaikum warahmatullahi wabarakatuh dan Salam Malaysia MADANI.

Syukur ke hadrat Allah S.W.T kerana dengan rahmat dan izin-Nya, 5th National Conference on TVET for Undergraduates Students (NCTS) 2025 dapat dianjurkan dengan jayanya di Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA).

Persidangan ini merupakan platform penting dalam menghimpunkan hasil penyelidikan dan inovasi para pelajar ijazah sarjana muda politeknik dari pelbagai bidang, selaras dengan keperluan Revolusi Industri 4.0 serta penguasaan kemahiran abad ke-21. Tema yang diangkat pada tahun ini, *"The Future in Our Hands: Empowering Youth for Technological and Social Advancement"*, amat bertepatan dengan aspirasi untuk memperkasa generasi muda sebagai pemacu transformasi negara masa hadapan.

NCTS merupakan salah satu platform penting dalam mencetus minat pelajar terhadap penyelidikan dan inovasi di samping memperkukuh kerjasama dengan industri serta merapatkan jurang antara teori dan aplikasi. Ia juga menggalakkan pemikiran reflektif dan pendedahan kepada pelbagai pendekatan penyelesaian masalah yang diperlukan dalam dunia pekerjaan mahupun kehidupan seharian masyarakat.

Saya ingin merakamkan setinggi-tinggi penghargaan kepada semua pihak yang telah menjayakan persidangan ini, khususnya Jabatan Pendidikan Politeknik dan Kolej Komuniti (JPPKK), serta Pusat Penyelidikan dan Inovasi (PPI) atas kepercayaan yang diberikan kepada PSA selaku tuan rumah.

Ucapan terima kasih turut ditujukan kepada Politeknik Ungku Omar, Politeknik Ibrahim Sultan dan Politeknik Sultan Azlan Shah serta seluruh jawatankuasa pelaksana NCTS 2025 atas kerja keras dan komitmen yang diberikan sepanjang penganjurannya.

Tahniah diucapkan kepada semua peserta. Semoga penganjuran NCTS terus menjadi pemangkin kepada pembangunan bakat negara yang kompeten, kreatif dan inovatif demi kemajuan negara tercinta.

PUAN ZAINAH BINTI RUJIHAN
Pengarah
Politeknik Sultan Salahuddin Abdul Aziz Shah

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1 TEKNOLOGI KEJURUTERAAN AWAM

A Field-Tested Centralized Material Logging System with Tiered Access for Civil Construction Teams

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ABSTRACT

In construction projects, poor material management caused by manual tracking methods—such as the use of spreadsheets and delivery receipts—can lead to delays, cost overruns, and inefficient coordination between departments. This study aims to solve these issues by developing a Centralized Material Management System (CMMS) for the 8MD3 Putrajaya construction project under Trans Resources Corporation Sdn Bhd. The objectives of the study were to identify material tracking problems on-site, design a centralized system to record and monitor all material orders and deliveries, and evaluate the system's performance and user acceptance. The system was built using PHP and Python, hosted on a local XAMPP server, and designed to meet the needs of various departments including Quantity Surveying, Logistics, and Operations. The platform enables manual input of Purchase Orders (PO) and Delivery Orders (DO), automatic calculation of undelivered quantities, and real-time data sharing among teams. To evaluate its effectiveness, a structured questionnaire survey was conducted with 31 users using the System Usability Scale (SUS), Technology Acceptance Model (TAM), and User Experience Questionnaire (UEQ). Results showed a high level of internal consistency (Cronbach's Alpha = 0.922) and strong user satisfaction in areas such as ease of use, time savings, data accuracy, and improved coordination. Some users noted minor issues with error messages and response speed, but overall, the CMMS proved to be a valuable tool in enhancing material tracking, reducing errors, and supporting more efficient construction workflows. The system also contributes to the industry's digital transformation and aligns with sustainable construction practices.

Keywords: material management, centralized systems, sustainable construction, material procurement lifecycle, python-driven material management

1.0 INTRODUCTION

Material management plays a pivotal role in the successful execution of construction projects, with materials typically accounting for over half of the total project cost (Durdyev et al., 2019). Ensuring that materials are delivered on time, accurately recorded, and efficiently distributed is essential for maintaining productivity and controlling costs. Despite its importance, many construction sites still rely on manual tracking systems such as spreadsheets, handwritten logs, and delivery receipts that are prone to human error, inconsistencies, and miscommunication (Ding et al., 2020). These outdated practices often lead to delays, material shortages, surplus inventory, and poor coordination among departments involved in procurement and site operations.

The increasing adoption of digital technologies in the construction industry offers promising opportunities to modernize material management practices. Centralized Material Management Systems (CMMS) are emerging as effective solutions to streamline the flow of information, enhance interdepartmental coordination, and support real-time tracking of materials throughout the construction lifecycle (Chin et al., 2021). Such systems consolidate purchase and delivery records into a single platform, providing stakeholders including quantity surveyors, logistics teams, and site managers with access to consistent, accurate, and up-to-date data (Zhang et al., 2022). Additionally, the integration of Artificial Intelligence (AI) and structured programming frameworks within these platforms contributes to greater data accuracy, automated tracking, and more efficient decision-making processes (Li et al., 2023).

This study focuses on the development and implementation of a CMMS specifically designed for the 8MD3 Putrajaya construction project, managed by Trans Resources Corporation Sdn. Bhd. The system addresses persistent issues in material tracking by replacing fragmented manual documentation with a centralized digital platform. Developed using PHP and Python, and deployed on a local XAMPP server, the system allows users to record and verify Purchase Orders (POs) and Delivery Orders (DOs), monitor undelivered quantities, and access real-time data for improved collaboration between departments.

The purpose of this research is to investigate the existing problems related to material tracking at the project site, to design and develop a centralized system that effectively records and monitors all material transactions, and to evaluate the system's usability, functionality, and user acceptance. Ultimately, this study seeks to improve material traceability, reduce human error, and enhance communication between project stakeholders, thereby contributing to more efficient construction workflows and supporting the industry's transition toward digital and sustainable practices.

2.0 METHODOLOGY

2.1 Study Area

This study was conducted at the 8MD3 construction project, an ongoing development located in Presint 8, Putrajaya, Malaysia. Managed by Trans Resources Corporation Sdn. Bhd. (TRC), the project involves the construction and completion of residential towers, serviced apartments, podium blocks, and retail spaces. Due to its scale and complexity, the project requires highly coordinated efforts in material procurement and site logistics. The 8MD3 site provided an ideal setting for the implementation and evaluation of the Centralized Material Management System (CMMS), as it involved multiple departments namely Quantity Surveying, Logistics, and Operations that regularly interact in managing construction materials. The site's active workflow and dynamic material movement allowed for real-time testing of the system's functionality and its impact on improving material tracking, minimizing errors, and enhancing interdepartmental communication. Conducting the study in an actual project environment such as 8MD3 ensures that the results reflect realistic challenges and practical applications, contributing to the credibility and relevance of the system's effectiveness.

2.2 Research Design

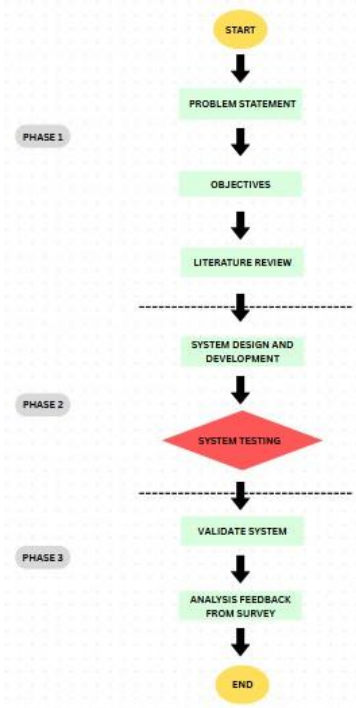

Figure 1. Methodology Framework

The methodology framework for this study consists of a systematic process starting from problem identification and ending with data analysis to evaluate the developed system. The process begins by defining the problem statement, which involves identifying material tracking challenges at the construction site. To gain a deeper understanding of the issues, interviews were conducted with key personnel, including the construction manager, quantity surveyor department, and logistics team. These interviews provided insights into current workflows and helped shape the project direction.

Following this, a literature review was conducted to study previous research and best practices in material management, centralized systems, and construction technology. This review served as the foundation for developing a solution that addresses the identified gaps.

Next, the data collection phase focused on gathering essential information related to the material ordering and receiving workflow at the 8MD3 site. This included reviewing purchase orders (PO), delivery orders (DO), and related records, which informed the application design.

The application design phase involved creating a centralized system tailored to user needs. If the initial design was not satisfactory during early testing, revisions were made before proceeding. Once the system was ready, it moved to the run application stage, where it was tested in a real project environment to track and verify selected materials.

After confirming that the application functioned as intended, the study proceeded to validate the application using a questionnaire-based survey. This qualitative research gathered user feedback on system effectiveness and interface usability from different departments involved in material management.

Finally, the responses were analyzed in the data analysis phase to evaluate the system's overall performance and identify areas for improvement. This structured methodology ensured that the CMMS was developed based on actual site needs and was tested and validated through real world application.

2.3 data Collection Process

The data collection process for this study was focused on gathering accurate and detailed information related to material transactions at the 8MD3 construction site. The primary data included records of Purchase Orders (POs) and Delivery Orders (DOs)**,** which were collected from the Quantity Surveyor and Logistics departments. Key information extracted from these documents comprised PO and DO numbers, material descriptions, quantities ordered and delivered, supplier details, and delivery dates. This data served as the foundational input for the development of the Centralized Material Management System (CMMS), allowing for structured tracking and comparison of ordered versus received materials. In addition to document review, interviews and on-site discussions were conducted with key stakeholders including the construction manager, quantity surveyor, and logistics personnel to understand the current material handling practices, identify workflow challenges, and define system requirements. This combination of document analysis and stakeholder engagement ensured that the system was tailored to meet the actual needs of end users, and that the data captured reflected real-time, site-specific material movement and coordination challenges.

3.0 RESULTS AND DISCUSSION

3.1 Limitations Of E isting Methods

Material management is a critical aspect of construction project success, yet many construction sites still rely on manual tracking methods such as spreadsheets, physical delivery receipts, and handwritten records. At the 8MD3 Putrajaya project, this traditional approach has led to various issues, including delays in delivery updates, lack of real-time information, and poor coordination between departments such as Quantity Surveying, Logistics, and Operations. Without

a centralized system, it is difficult to monitor outstanding deliveries, track material usage accurately, or ensure timely procurement. These inefficiencies often result in over ordering, material wastage, and increased project costs. Therefore, a centralized, digital solution is needed to improve data accuracy, enhance communication, and support more efficient material tracking across all departments involved in the project.

3.2 Interface Design for Different User Roles

3.2.1 Quantity Surveyor Interface

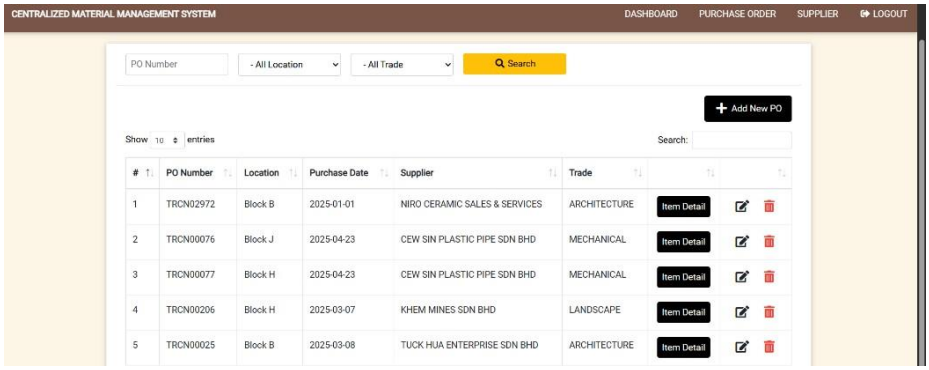

Figure 2. Quantity Surveyor Interface

The Quantity Surveyor (QS) interface in the Centralized Material Management System (CMMS) serves as the main control panel for managing all Purchase Orders (POs). It allows the QS to enter key details such as PO number, site location, supplier name, and trade category. The interface features search tools, filters, and editable tables to help manage large volumes of data efficiently. By replacing manual records and spreadsheets, the system improves data accuracy, enhances material tracking, and supports better coordination with suppliers and project teams.

3.2.2 Logistic Department Interface

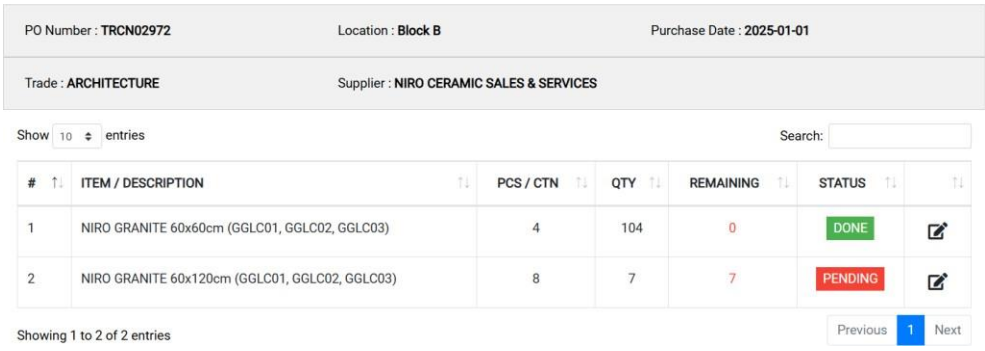

Figure 3. Logistic Department Interface

This interface is designed for the Logistics Department in the Centralized Material Management System (CMMS) to help staff verify and update construction materials received on-site. It shows key details like PO number, project location, purchase date, supplier, and trade, along with a table listing each ordered item and its quantity. The logistics team uses this information to check deliveries against purchase orders and physical stock, updating quantities as needed. They can also add, edit, or delete items to ensure accurate records. This system improves communication between procurement and site teams, ensures precise material tracking, and helps prevent errors or losses for smoother construction operations.

3.2.3 Operation Department Interface

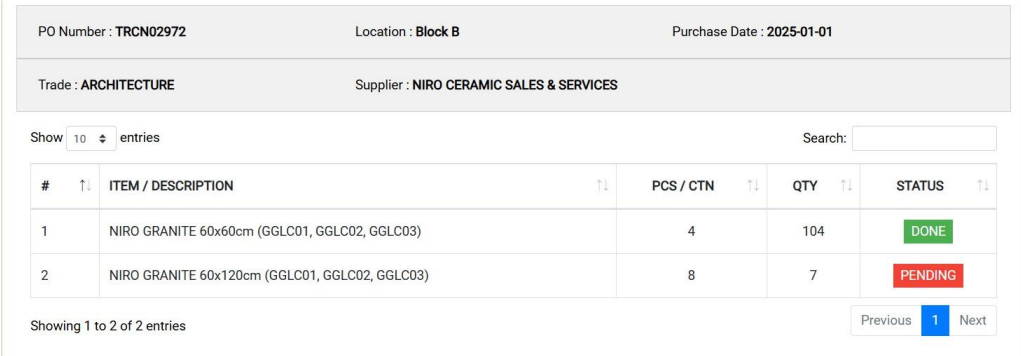

Figure 4. Operation Department Interface

This interface is for the Operation Team in the Centralized Material Management System (CMMS) to monitor materials ordered and delivered to the construction site in real-time. Unlike other teams, they cannot edit data but only view important details like PO number, site, purchase date, supplier, and trade, along with a list of items showing descriptions, quantities, and delivery status. Items are labelled and color-coded as "DONE" (delivered) or "PENDING" (waiting), helping the team quickly understand material availability. This allows the Operation Team to plan site work and labor efficiently, avoid delays, and keep construction activities running smoothly by staying updated on material progress.

3.3 Analysis of the Effectiveness of the System

Table 1. Feedback of the System

No	Feedback of CMMS	Level of Agreement				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
B1	The system is easy to use and navigate.	N/A	6 (19.4%)	11 (35.5%)	14 (45.2%)	N/A
B2	The interface is user-friendly and intuitive.	N/A	6 (19.4%)	18 (58.1%)	7 (22.6%)	N/A
B3	Training or guidance provided was sufficient to operate the system.	N/A	7 (22.6%)	15 (48.4%)	9 (29%)	N/A
B4	Error messages or issues are clearly communicated.	N/A	10 (32.3%)	14 (45.2%)	7 (22.6%)	N/A
C1	The system performs tasks efficiently without significant delays.	N/A	8 (25.8%)	14 (45.2%)	9 (29%)	N/A
C2	System loading times are acceptable.	N/A	5 (16.1%)	17 (54.8%)	9 (29%)	N/A

C3	The system integrates well with existing workflow (e.g., Purchase Orders, Delivery Notes).	**N/A**	**5 (16.1%)**	**18 (58.1%)**	**8 (25.8%)**	**N/A**
C4	Data entry and retrieval are fast and responsive.	**N/A**	**10 (32.3%)**	**15 (48.4%)**	**6 (19.4%)**	**N/A**
D1	The system reduces data entry errors.	**N/A**	**5 (16.1%)**	**18 (58.1%)**	**8 (25.8%)**	**N/A**
D2	Material records are consistently accurate and up-to-date.	**N/A**	**9 (29%)**	**11 (35.5%)**	**11 (35.5%)**	**N/A**
D3	The system helps ensure accountability and traceability of materials.	**N/A**	**8 (25.8%)**	**14 (45.2%)**	**9 (29%)**	**N/A**
E1	The CMMS has improved the overall material management process.	**N/A**	**6 (19.4%)**	**16 (51.6%)**	**9 (29%)**	**N/A**
E2	The system has reduced time spent on manual data entry.	**N/A**	**7 (22.6%)**	**13 (41.9%)**	**11 (35.5%)**	**N/A**
E3	Communication between site and office has improved due to the system.	**N/A**	**8 (25.8%)**	**15 (48.4%)**	**8 (25.8%)**	**N/A**

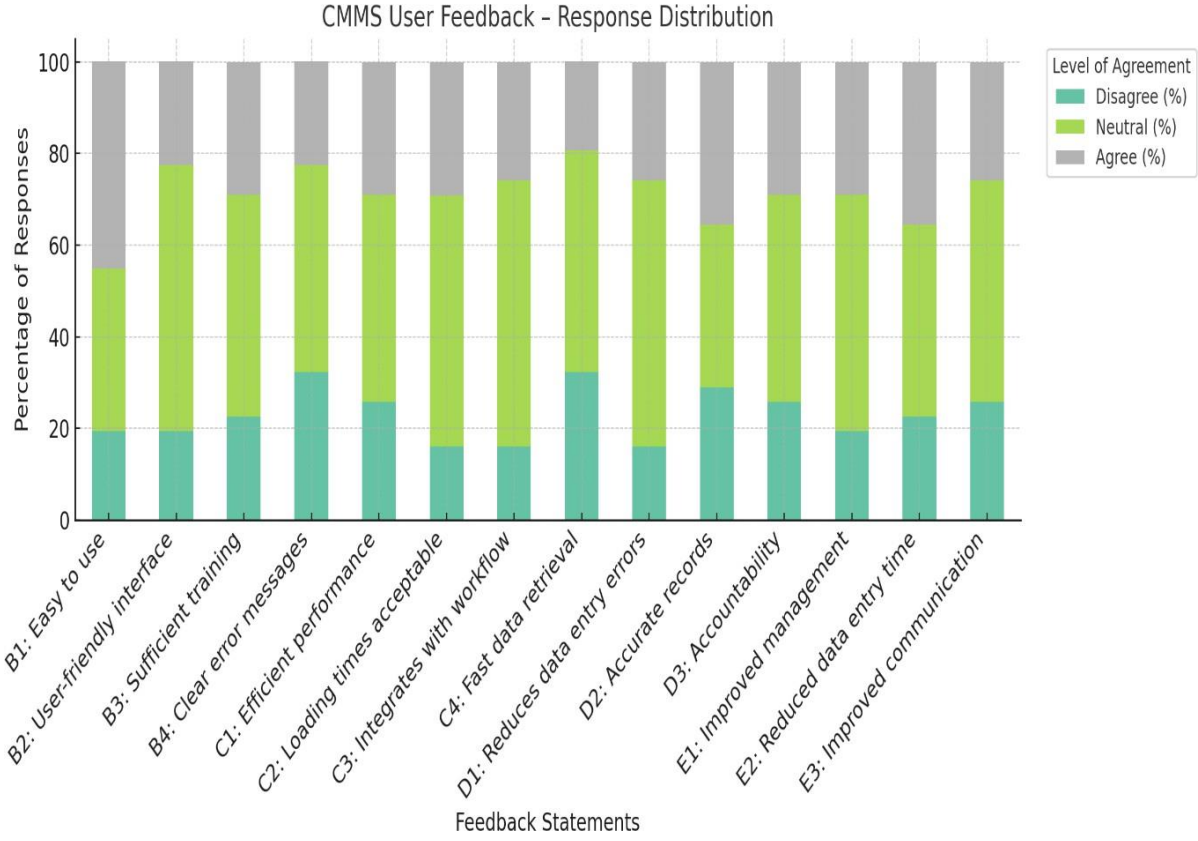

Figure 5. Chart Feedback

A frequency analysis was conducted to evaluate user perceptions of the Centralized Material Management System (CMMS) across 14 questionnaire items using a 5-point Likert scale. The results indicate that respondents generally held neutral to positive views about the system. In terms of usability, 45.2% of respondents agreed that the system is easy to use and navigate (B1), while 35.5% remained neutral. Similarly, for the system's interface being user-friendly and intuitive (B2), 58.1% selected neutral, and 22.6% agreed. Regarding training and communication, 48.4% of respondents were neutral on the sufficiency of training or guidance provided (B3), and 29% agreed. However, a notable proportion (32.3%) disagreed that error messages or issues are clearly communicated (B4), indicating a need for improvement in user feedback and system alerts.

When assessing performance and responsiveness, 45.2% of respondents were neutral and 29% agreed that the system performs tasks efficiently without delays (C1). Regarding system loading times (C2), over half (54.8%) were neutral, which suggests moderate satisfaction but also highlights an area for technical improvement. For system integration with existing workflows such as purchase orders and delivery notes (C3), 58.1% were neutral and 25.8% agreed. However, responses to the system's data retrieval speed (C4) were less favourable, with 32.3% disagreeing and only 19.4% agreeing, indicating concerns with system responsiveness.

In terms of data management, 58.1% of respondents were neutral on the system's ability to reduce data entry errors (D1), while 35.5% agreed that material records are accurate and up to-date (D2). For the system's ability to ensure accountability and traceability (D3), responses were mixed, with 45.2% neutral and 25.8% disagreeing. Regarding overall material management, 51.6% of participants were neutral and 29% agreed that the CMMS has improved the process (E1). A similar trend was observed in reduced time spent on manual data entry (E2), with 41.9% neutral and 35.5% agreeing. Lastly, communication between site and office staff (E3) was also viewed cautiously, with 48.4% neutral and 25.8% disagreeing.

These findings suggest that while there is no strong opposition to the CMMS, many users maintain a neutral stance, indicating possible gaps in training, system responsiveness, and interface communication. The results highlight the need for improvements in user engagement, clearer communication of system feedback, and enhanced performance features to increase overall user satisfaction and acceptance.

4.0 CONCLUSION

The system validation results, based on responses from 31 participants across different departments involved in the 8MD3 Putrajaya project, show that the Centralized Material Management System (CMMS) successfully addressed key problems such as fragmented data recording, poor communication, and delays in tracking materials. Descriptive statistics revealed that most items scored between 2.87 and 3.26 on average, indicating positive feedback. The highest ratings were for system usability, time savings, and improved team coordination, demonstrating that the CMMS effectively replaced manual tracking and streamlined workflows. Consistent standard deviation values suggest broad agreement among users on the system's usefulness. While some users pointed out issues with error notifications and system responsiveness, these insights offer valuable directions for future improvements, particularly in user interface design and technical performance. Overall, the feedback reflects high satisfaction, with many agreeing that the CMMS enhanced data accuracy, reduced duplicate records, and provided better real-time visibility of material deliveries. In summary, the findings strongly support the CMMS as an effective and reliable tool for improving construction material management, fostering better communication, and reducing inefficiencies, highlighting its potential for wider application in the industry's digital transformation.

ACKNOWLEDGEMENT

Special thanks go to the team and personnel involved in the 8MD3 Putrajaya project, whose cooperation and willingness to share information made this study possible. My sincere appreciation goes to my family and friends for their unwavering support, motivation, and understanding during the challenges of this project.

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Centralized Tracking System For Materials In Construction Projects

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ABSTRACT

Effective material tracking is essential during the Defect Liability Period (DLP) in construction, where timely access to stored materials is critical for rectification work. However, many sites still rely on manual logbooks and ad hoc spreadsheets, resulting in undocumented inventory, coordination delays, and miscommunication between departments. This study aims to address these issues through the development and evaluation of a centralized material tracking prototype tailored for site-level implementation. To achieve this, the research was structured into three phases. First, interviews with construction personnel were conducted to identify current material management challenges. Second, a prototype system was developed using PHP and deployed via Hostinger, incorporating features such as material registration, storage zoning, document uploads, and inventory summaries. Third, the system was evaluated through a user survey involving 20 site personnel from various roles. The findings revealed that existing site practices are inefficient, confirming the need for digital intervention. The developed prototype successfully addressed key site level requirements and received positive feedback for usability, workflow integration, and communication enhancement, with an overall average rating of 4.04. This research demonstrates the feasibility of implementing lightweight, cost effective tracking systems in construction contexts and lays the foundation for future deployment, particularly in projects with small and medium sized enterprises (SMEs) like constraints or low digital maturity.

Keywords: centralized system, material tracking, digitalize material management, web based, operational efficiency.

1.0 INTRODUCTION

The construction industry continues to encounter persistent inefficiencies in material tracking and logistics, particularly on dynamic job sites where the flow of materials is critical to timely project delivery. These inefficiencies are often the result of manual documentation, poor communication between departments, and siloed data systems that prevent real-time coordination. Ineffective tracking of materials not only leads to schedule disruptions but also contributes to material wastage, labor inefficiencies, and higher project costs. As observed by Wibowo et al. (2017), improper coordination in material supply chains is a leading contributor to delays and cost escalations, particularly in urban construction environments where logistical complexity is high.

Despite the proliferation of digital solutions in other sectors, the adoption of such technologies in construction particularly among SMEs remains limited. Rana Matarneh et al. (2024) identified multiple barriers including unclear return on investment (RoI), insufficient leadership commitment, low digital competence, and organizational resistance, all of which hinder widespread adoption of digital supply chain tools. These factors contribute to continued reliance on paper-based methods, especially among projects operating under resource constraints.

Although platforms such as blockchain and ERP systems offer traceability and integration benefits, they are often seen as impractical for small scale projects due to high costs and complex setup requirements. This is supported by Basheer et al. (2024), who proposed a

blockchain-based material management system but acknowledged its limitations in terms of scalability for non enterprise settings. Similarly, conventional cloud platforms or BIM-based systems may introduce excess functionality and technical overhead not aligned with SME capabilities.

Recognizing these barriers, several scholars have called for the development of lightweight, user-friendly, and context-specific tools that align with the operational realities of construction SMEs. Chong et al. (2014) emphasized that cloud computing, when tailored correctly, can significantly reduce fragmentation and enhance real-time decision-making even within digitally immature organizations. Xu et al. (2018) further noted the viability of IoT enabled platforms combined with simplified cloud architecture to enhance lean practices without overburdening users with technological complexity.

In response to these gaps, this study introduces a centralized tracking platform built with PHP and deployed via Hostinger. The system is designed to address common pain points in construction material management such as undocumented storage zones, uncoordinated delivery timing, and the absence of real-time updates while remaining affordable and easy to deploy. By focusing on simplicity, accessibility, and context-specific functionality, this initiative aligns with ongoing efforts to digitally uplift small construction projects in Malaysia.

The objectives of this study are threefold (1) to identify the current material handling process problems and propose solutions, (2) to create a prototype to track material balance and storage locations on site with high accuracy and ease of use, and (3) to evaluate the effectiveness of the application in construction site. The proposed solution contributes to Malaysia's broader digitalization agenda in construction and offers a replicable model for cost effective technology adoption in SME-led projects.

2.0 METHODOLOGY

The methodology of this study is divided into three structured phases, reflecting the project's development lifecycle from problem definition to evaluation. The approach is informed by design thinking principles and aligns with standard practices for digital tool implementation in construction site environments. The first phase began with the empathize and define stage, where informal discussions with site personnel including project managers and engineers helped identify key issues in current material tracking workflows. This was followed by establishing the problem statement and objectives. A focused literature review was conducted to frame the study and assess the relevance of digital solutions for construction logistics. To find out more about material management method that being used on site, interview with construction personal that main work involve managing material logistic. Insights from interviews directly informed the interface design, particularly the need for real time visibility, simplified forms, and on-screen summaries of stored materials

In the second phase, the centralized material tracking system was designed and developed using PHP as the backend language and hosted on Hostinger. The application features several key interfaces involving login page, material registration, material tracking and documentation upload page. The centralized material tracking prototype was developed using PHP as the primary server-side scripting language and hosted via the Hostinger cloud platform. PHP was chosen due to its compatibility with MySQL databases, cost-effectiveness, and flexibility for developing dynamic web applications. The system architecture was modular, with database connection script establishing a persistent database connection across all modules. User authentication was implemented through login interface script, which handled login credentials

and session initialization, while new user registration was managed in user registration module. Upon successful login, users were redirected to main dashboard interface, a protected interface that displays real-time material data retrieved from the database via structured queries. Material records, including identifiers, status, and location, were managed through material tracking and update module, which facilitated data entry and updates using parameterized SQL statements to ensure security and prevent SQL injection. The incentory summary retrieval script was responsible for retrieving inventory summaries and presenting them dynamically on the dashboard. A session termination script ensured proper session termination and redirected users securely to the login interface.

The system was deployed on Hostinger, utilizing its built in cPanel to manage domain configuration, database hosting via phpMyAdmin, and secure file transfers through the File Manager. Hostinger's support for SSL certificates and cron job scheduling also enabled secure connections and potential automation features. Overall, the development process emphasized modularity, data integrity, and ease of access, aligning with the project's objective to provide a centralized, web based material tracking platform for improved coordination in construction projects. The system was designed as a responsive web-based platform to ensure cross device accessibility via desktops, tablets, and smartphones.

Although the testing and demonstration of the centralized tracking prototype were conducted in collaboration with Sunway Construction, a well-established enterprise in the Malaysian construction sector, the selected project site Sunway Quay Square operated under conditions that closely resembled those of SMEs. During the internship period, it was observed that material tracking at the site heavily relied on manual logbooks, Excel spreadsheets, and verbal communication between departments. No integrated inventory platform or centralized digital recordkeeping was in use. Despite Sunway's corporate access to advanced systems such as ERP and BIM, these tools were not deployed at the site level for material logistics. This fragmentation and limited system usage at the operational tier reflect the common constraints faced by SME led construction projects, including low digital maturity, limited IT infrastructure, and minimal automation. Therefore, the implementation of the proposed tracking system within this constrained environment not only validates its effectiveness in real world settings but also strengthens its relevance for SMEs that typically lack access to enterprise-scale digital tools.

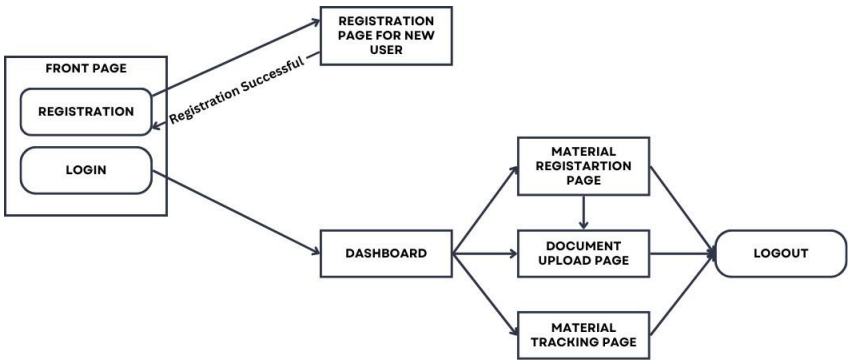

Figure 1: User interaction flow of the centralized material tracking system prototype.

Figure 1 illustrates the interaction flow of the centralized material tracking system prototype. The process begins at the front page, where users can either register or log in. Upon successful registration or login, users are directed to the main dashboard, which acts as the central navigation hub. From the dashboard, users can access several core functions including the Material Registration Page, Material Tracking Page, and Document Upload Page. These modules support the entry, updating, and documentation of material inventory data. After

completing their tasks, users can securely exit the system via the logout function. The flow was designed to reflect typical construction site workflows, prioritize usability, and minimize complexity for new users. This structure supports efficient navigation, ensures data integrity, and aligns with the objective of enabling real-time coordination across site teams.

Lastly at third phase, the application was demonstrated to a selected group of 20 construction professionals, including supervisors, planners, and site engineers. The study deployed a survey design via questionnaire for data collection. To assess system performance, questions across four key dimensions involving usability, effectiveness, collaboration and communication, and satisfaction with future use are distributed via Google Form. Demographic respond also being collected to understand the role of responder in construction, gender of respondent and experience in construction industry. Except demographic and open end question, all question use the five scores Likert Scale from strongly disagree (score 1) to strongly agree (score 5). Respondents were asked to give their rate based on the five-scale score for every question except for demographic question and open end question.

Table 1: Interpretation Scale for Cronbach's Alpha Internal Consistency

Cronbach's alpha	Internal Consistency
0.9 and above	Excellent
0.80-0.89	Good
0.70-0.79	Acceptable
0.60-0.69	Questionable
0.50-0.59	Poor
below 0.50	Unacceptable

The evaluation data was further supported by a reliability analysis using Cronbach's Alpha, confirming internal consistency among the responses. Table 1 show the interpretation scale for Cronbach's Alpha internal consistency where it show the consistency of responds based on value achieved after calculation. Insights from this phase informed potential refinements and highlighted areas for future expansion. This three-phase methodology provided a systematic framework for investigating the feasibility and impact of centralized material tracking in a real-world construction context.

While the study demonstrates the feasibility and relevance of a centralized tracking system in construction contexts, certain limitations must be acknowledged. First, the system was not fully deployed on an active construction project but was instead demonstrated to users in a controlled setting. As such, the findings may not fully capture challenges that could arise during live implementation, such as network instability, resistance to change, or integration with existing workflows. Second, the user evaluation relied on responses from only 20 construction professionals, which, although diverse in roles, limits the generalizability of the results. Broader field testing across multiple project sites and longer evaluation durations would be necessary to assess the system's robustness, adaptability, and long-term user adoption under varying real-world conditions.

3.0 RESULTS AND DISCUSSION

Site level interviews with construction personal revealed that the existing material management process primarily relied on manual methods such as handwritten logbooks and spreadsheet entries. These practices resulted in several operational issues, including delayed material

identification, miscommunication among departments, and inefficient tracking of delivery status. Respondents reported that locating materials often consumed excessive time due to undocumented storage locations. These inefficiencies highlighted the need for a centralized platform to improve coordination, visibility, and material traceability.

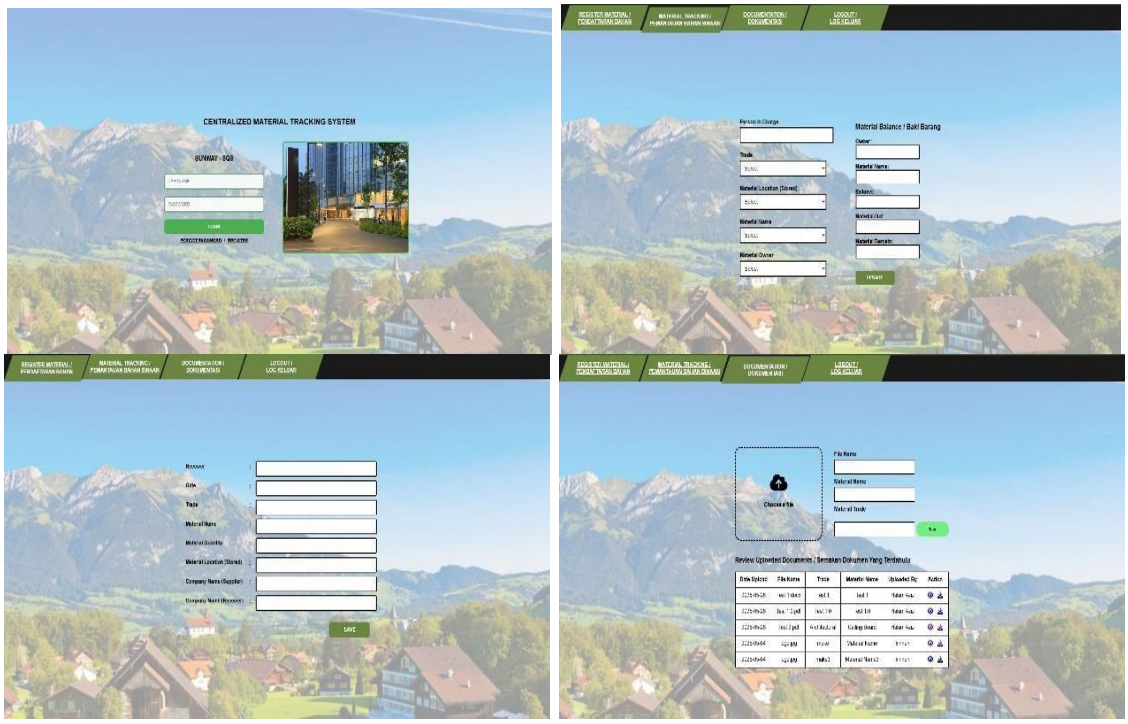

Figure 2: User Interface of tracking prototype.

The user interface of the centralized tracking prototype as shown in Figure 2 was designed to prioritize clarity, ease of navigation, and logical task flow critical factors for construction site usability. The Login Page serves as the entry point, where authorized personnel authenticate before accessing the system. Upon successful login, users are directed to the Dashboard, which acts as a centralized hub linking all major functions. The Material Registration Page enables users to input key material data, including descriptions, quantities, and delivery information. The Material Tracking Page allows for real-time updates to material status and location, supporting visibility across departments. The Document Upload Page facilitates the digital storage of delivery receipts or inventory verification records, reducing reliance on manual filing. Finally, the system includes a Logout function to ensure session security. The layout and interaction design reflect user-centred principles, aligning with feedback gathered during site level demonstrations and ensuring that even users with limited digital experience can operate the system effectively.

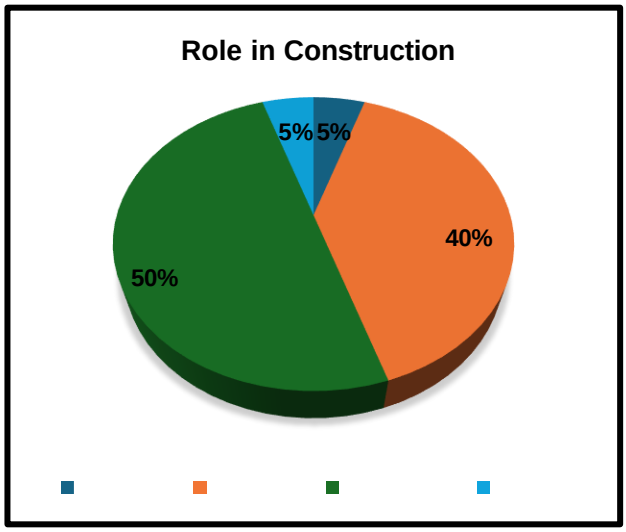

Figure 3: Role distribution of respondent.

The evaluation of the centralized material tracking system involved a quantitative analysis based on feedback from 20 construction personnel at the Sunway Quay Square project. Respondents comprised a diverse group of site stakeholders, including supervisors (50%), engineers (40%), project managers (5%), and planners (5%), as illustrated in Figure 3. This role distribution reflects the system's exposure to multiple functions within the site workflow and ensures that feedback encapsulates a wide spectrum of operational perspectives.

Table 2: User Evaluation Scores

No	Item		Percentage (%)					Mean	SD
			1	2	3	4	5		
1	System Usability	Easy to navigate	0	0	10% (2)	70% (14)	20% (4)	4.10	0.553
2		Visual layout supports access	0	0	10% (2)	65% (13)	25% (5)	4.15	0.587
3		Mobile access usability	0	0	20% (4)	55% (11)	25% (5)	4.05	0.686
4	System Effectiveness	Helps reduce delays	0	0	25% (5)	60% (12)	15% (3)	3.90	0.641
5		Improves computer literacy	0	0	10% (2)	70% (14)	20% (4)	4.10	0.553
6	Collaboration and Communication.	Improves team communication	0	0	20% (4)	45% (9)	35% (7)	4.15	0.745
7		Efficient document sharing	0	0	35% (7)	30% (6)	35% (7)	4.00	0.827
8		Improves interdepartent coordination	0	0	15% (3)	65% (13)	20% (4)	4.05	0.605
9	Satisfaction and Future Use	Overall satisfaction	0	0	20% (4)	55% (11)	25% (5)	4.05	0.686
10		Recommendation to others	0	0	30% (6)	60% (12)	10% (2)	3.80	0.616
Average								4.04	

SD = Standard Deviation

The user evaluation scores in Table 2 reveal that the centralized material tracking prototype was generally well received, with average ratings above 4.0 across most dimensions. High scores in usability particularly in navigational simplicity (M = 4.10) and visual layout (M = 4.15) indicate that the system interface was intuitively designed and accessible even for users with limited digital experience. This aligns with Chong et al. (2014), who emphasized that successful digital adoption in construction depends heavily on user-friendly interfaces tailored to site-level realities.

Effectiveness ratings also suggest promising impact, with the system perceived as reducing delays (M = 3.90) and enhancing basic digital skills (M = 4.10). These outcomes are consistent with observations from the methodology phase, where many site tasks previously relied on paper based or spreadsheet methods. The system's ability to standardize and centralize data likely improved planning visibility and reduced ambiguity in material status communication.

In the domain of collaboration and communication, scores for team communication (M = 4.15) and interdepartmental coordination (M = 4.05) reinforce the prototype's role in improving cross role transparency. However, the relatively higher standard deviation in efficient document sharing (SD = 0.827) suggests mixed experiences across respondents, possibly due to variations in digital literacy, role expectations, or access to device compatibility on-site. This variance highlights the need for additional training or interface refinement tailored to different user categories.

Interestingly, the item recommendation to others received a slightly lower average score (M = 3.80), which may indicate some hesitation among users to fully endorse the system despite recognizing its value. This could stem from limitations not yet addressed such as offline access or material photo logging as mentioned in the open-ended feedback. As Matarneh et al. (2024) have shown, perceived usefulness alone is often insufficient for full adoption; ease of integration and contextual fit are equally critical.

Overall, the quantitative findings support the system's functional validity while also uncovering areas requiring refinement. These results reflect a solid proof of concept, with high internal reliability (Cronbach's Alpha = 0.806) and generally favourable reception, yet they also point toward the importance of iterative development, role-based optimization, and long-term validation in live project cycles.

Complementing the quantitative findings, open ended survey responses were analyzed to capture more nuanced user insights regarding the centralized tracking prototype. Respondents provided constructive feedback that highlighted both the perceived strengths of the system and suggestions for future enhancement. These comments reflect practical needs and usability expectations grounded in real construction workflows. Several users emphasized the importance of real time awareness and proactive system interaction. One common suggestion was to add a notification function that could alert relevant personnel when new materials are registered, updated, or delayed. This would streamline coordination and reduce the need for follow-up communication. Another respondent proposed integrating a photo feature to visually document the condition of materials upon delivery or at storage, which would help ensure accountability and reduce disputes related to damaged or non-conforming goods.

Respondents also highlighted the need for contextual quantity tracking. Specifically, one recommendation involved displaying the required amount of material for each construction stage, which would allow site personnel to compare deliveries with planned consumption and identify shortages early. In terms of spatial logistics, users requested the inclusion of a layout visualization for storage zoning, including designated and allowed areas for specific types of materials. This would enhance on-site navigation and reduce misplacement or overcrowding.

To further increase accessibility, some users advocated for the integration of QR code scanning, enabling instant access to material details or specific location data via mobile devices. Finally, a crucial suggestion was to enable offline functionality, ensuring that the system remains usable even in low-connectivity areas a common limitation on large or remote construction sites.

Collectively, these open ended responses provide valuable direction for future iterations of the tracking platform. They underscore the need for enhanced automation, spatial awareness, data portability, and offline resilience features that would further align the system with the practical demands of construction environments.

4.0 CONCLUSION

This study set out to address persistent inefficiencies in construction material management by developing and evaluating a centralized tracking prototype tailored for site-level implementation. Through a structured methodology combining interviews, system design, and user evaluation, the research demonstrated that a lightweight, web-based solution can significantly enhance visibility, coordination, and digital documentation of material handling processes. The prototype achieved high usability and satisfaction scores among construction professionals, indicating its potential to streamline workflow and reduce time lost to fragmented tracking practices.

However, several limitations must be acknowledged. The system was developed and tested as a prototype rather than a fully deployed platform due to time, scope, and access constraints typical of an academic final year project. It was evaluated in a simulated environment rather than being embedded into an ongoing project cycle. Additionally, some features such as offline access, dynamic quantity tracking by work stage, and photo-based material verification were conceptualized but not implemented. These limitations reflect the pragmatic boundary between concept validation and full-scale deployment.

Despite these constraints, the research provides a strong foundation for further exploration. Future iterations could expand functionality by integrating mobile app versions, QR code scanning, and automated notifications. Collaboration with industry partners could also facilitate live testing in real project environments, providing insights into long term user behaviour, scalability, and system resilience under operational pressures. By refining this system through iterative development and expanding its adoption across project types, this research opens the door to a more connected, transparent, and efficient future for construction material tracking.

ACKNOWLEDGMENT
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Comparison Of Stability Performance Between Precast Concrete Piles And Geopolymer Concrete Piles

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ABSTRACT

This study compares the stability performance of precast concrete piles (PCP) and geopolymer concrete piles (GPCP) in foundation engineering, with an emphasis on structural efficiency and environmental sustainability. As the building industry strives for sustainable growth, the environmental consequences of conventional materials like ordinary Portland cement (OPC) used in precast concrete have raised serious concerns due to their high carbon footprint. This research examines geopolymer concrete as an eco-friendly alternative that uses industrial by-products like fly ash and slag, lowering CO_2 emissions while maintaining equivalent mechanical properties. To analyze and compare the performance of PCP and GPCP, PLAXIS 2D software was used to run a series of simulations under various loading circumstances and soil types, such as sandy, clayey, and silty. To reduce geometric bias, the piles were exposed to incremental axial loads, and their behaviours were examined in terms of load-settlement response, deformation, and safety considerations. Furthermore, the study incorporates sustainable building concepts by emphasizing the environmental advantages of geopolymer technology, such as lower embodied energy and increased durability in harsh conditions. Although geopolymer concrete produces promising outcomes, issues such as diversity in raw material composition and low standardization continue to impede wider implementation. Nonetheless, the findings of this study show that geopolymer piles can function as well as precast concrete piles in many situations. As a result, this study provides vital insight into the advancement of sustainable foundation systems and encourages the use of new materials in current geotechnical engineering techniques.

Keywords: Geopolymer Concrete, Precast Concrete Piles, PLAXIS 2D Simulation, Finite Element Analysis, Alternative Cementitious Materials

1.0 INTRODUCTION

Sustainable building has emerged as a primary emphasis in modern construction, motivated by the need for ecologically benign approaches that simultaneously serve economic and social objectives. It supports the use of renewable resources, decreased waste, and energy-efficient technology to enhance building performance and reduce environmental impact, all of which are aligned with the United Nations Sustainable Development Goals. The building industry contributes significantly to greenhouse gas emissions, particularly via the use of ordinary Portland cement (OPC), which accounts for around 8% of worldwide CO_2 emissions. Precast concrete piles, which are well-known for their strength and dependability, rely largely on OPC, presenting sustainability problems. Geopolymer concrete, an alternative, employs industrial waste materials such as fly ash and slag to make a lower-carbon solution with high strength, durability, and chemical and heat resistance, making it acceptable for foundation construction. However, its wider application is hampered by issues like as raw material availability, greater beginning costs, and the requirement for specialist knowledge in mix design. As a result, more testing of its performance under real-world soil and loading circumstances is required to demonstrate its suitability for wider use in sustainable building.

The construction business is evolving to satisfy the increasing need for more sustainable, efficient, and long-lasting building solutions. One major focus is on employing low-carbon materials like geopolymer concrete and dependable foundation solutions like precast concrete piles. Cement manufacture, particularly for precast piles, accounts for around 8% of worldwide CO_2 emissions,

creating environmental concerns (Habert et al., 2020). Geopolymer concrete, manufactured from industrial waste such as fly ash and slag, is a greener option that reduces emissions while increasing durability (Van Deventer et al., 2012). Precast piles are popular because of their strength and ease of installation, but they rely primarily on conventional Portland cement, which is both energy-intensive and toxic (Das and Sivakugan, 2018; Neville and Brooks, 2010). In contrast, geopolymer piles may cut emissions by up to 80% and withstand extreme conditions such as chemicals and heat, making them appropriate for coastal or industrial sites (Sharma et al., 2019). However, their use remains limited due to difficulties such as uneven raw material quality and a lack of common design codes (Huseien et al., 2021). According to studies, geopolymer piles may outperform precast piles in terms of strength and endurance, but the decreasing supply of fly ash may limit their future usage. Overall, there is a great need to embrace more environmentally friendly foundation systems, and with more study and standardization, geopolymer concrete piles might become an important answer for sustainable building.

The construction sector is confronted with the significant challenge of reconciling structural integrity with environmental sustainability. Precast concrete piles, known for their exceptional load-bearing capabilities and longevity, predominantly utilize ordinary Portland cement (OPC). This reliance substantially contributes to carbon dioxide emissions, raising concerns amid the global initiative to mitigate environmental impacts (Scrivener et al., 2018). Conversely, geopolymer concrete piles, which are produced from industrial by-products like fly ash and slag, present a viable sustainable alternative. These piles not only diminish carbon emissions but also exhibit remarkable resistance to chemical corrosion and environmental deterioration (Van Deventer et al., 2012). Nevertheless, despite their potential advantages, there exists a scarcity of research regarding the long-term stability performance of geopolymer concrete piles under diverse load and soil conditions, which hampers their broader implementation in construction practices (Huseien et al., 2021).

To bridge this knowledge gap, the present study examines the comparative stability performance of precast concrete piles versus geopolymer concrete piles. It specifically aims to address two pivotal research inquiries on how do the stability performance of precast concrete piles measure up against those of geopolymer concrete piles? Furthermore, can geopolymer concrete piles be considered a sustainable and dependable alternative to precast concrete piles in foundation engineering? By exploring these questions, the study aspires to offer significant insights into the viability of utilizing geopolymer concrete piles for sustainable and structurally robust construction solutions.

The primary purpose of this study is to examine the stability of precast and geopolymer concrete piles in foundation engineering. Models of both pile kinds will be produced using their material attributes and forms. Simulations will be performed with PLAXIS 2D to determine how the piles respond under various loads and soil conditions. Their performance will be evaluated utilizing critical parameters such as load-settlement behavior, deformation, and stability. This method contributes to determining if geopolymer piles are a realistic and sustainable alternative to typical concrete piles.

The purpose of this study is to examine and compare the performance of Geopolymer Concrete Piles (GPCP) and Precast Concrete Piles (PCP) using PLAXIS 2D numerical simulation. Both pile types are modelled with conventional dimensions of 20 meters in length and 1.2 meters in diameter, and they are subjected to a sustained axial load of up to 12,000 kN to imitate actual structural conditions. The investigation is carried out in a sandy silt soil environment that simulates normal

geotechnical conditions. Load-settlement behaviour, deformation, and safety factor are among the key criteria considered.

This study promotes sustainable building by comparing the performance of Geopolymer Concrete Piles (GPCP) with standard Precast Concrete Piles (PCP) in sandy silt soil using PLAXIS 2D simulations. Geopolymer concrete, manufactured from industrial wastes such as fly ash and slag, is a low-carbon alternative to traditional concrete that has comparable or higher strength. The study looks at critical characteristics including settling, deformation, and safety, offering useful information on how GPCPs operate under actual settings. It addresses a knowledge gap in geotechnical engineering and provides insights that can help guide the implementation of greener foundation systems.

2.0 METHODOLOGY

This study uses a systematic approach to examine the stability of precast concrete piles with geopolymer concrete piles. As shows on figure 1, starts with gathering data, such as site investigation reports, pile size, and load test results, and then determining essential parameters for soil, concrete, and geopolymer materials. The design process entails developing precise models of the pile-soil system, which include soil and pile material behavior. A finite element simulation is then performed, which includes material modeling, meshing, load application, and staged building. Data from the simulation, such as settlement and stress responses, are retrieved and examined to determine the performance and stability of different pile types under identical conditions.

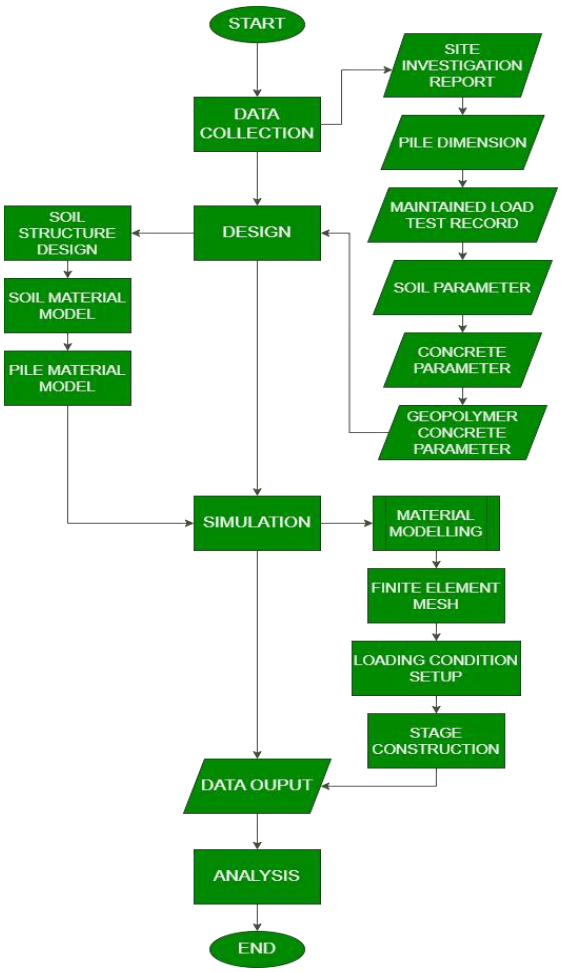
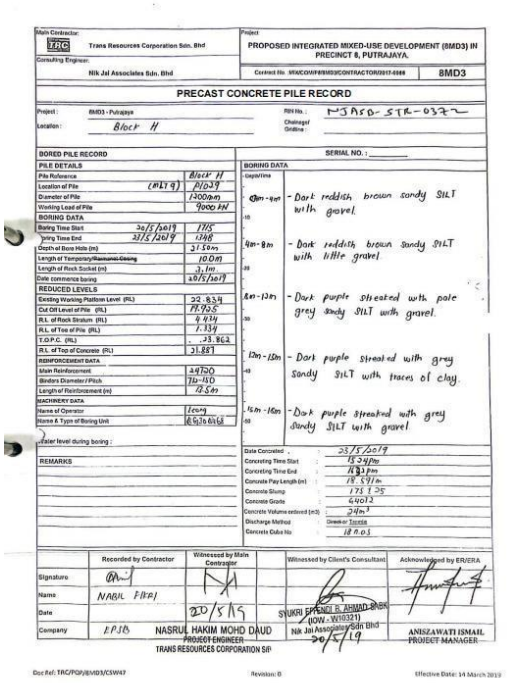


Figure 1: Methodology Flow Chart

2.1 Data Collection Approach

This study begins with a thorough data gathering phase, which is necessary for creating an accurate and realistic simulation model. The data gathered contains numerous essential inputs required to assess the stability of precast concrete piles and geopolymer concrete piles. All data is acquired from relevant and credible sources, including engineering reports, field test results, and material specifications.

The Site Investigation Report is the first source of data, and it contains thorough information on subsurface soil conditions at the Trc Corporation Sdn Bhd, 8MD3 project. This includes data on soil layers, groundwater levels, and soil physical qualities, all of which are critical for understanding how the pile interacts with the earth.



PROPOSED INTEGRATED MIXED-USE DEVELOPMENT (8MD3) IN PRECINCT 8, PUTRAJAYA.

8MD3

PRECAST CONCRETE PILE RECORD

Figure 2 : Site Investigation Report

Additional material attributes are also gathered and organized into three major areas. The first is the soil parameter, which comprises cohesion, internal friction angle, modulus of elasticity, and Poisson's ratio. These characteristics determine the strength and deformability of the soil. The second is the Concrete Parameter, which specifies mechanical parameters such as compressive strength and density for standard precast concrete piles. Finally, the Geopolymer Concrete Parameter is compiled, which comprises particular values related to geopolymer concrete, such as its varying curing behaviour, strength qualities, and modulus of elasticity.

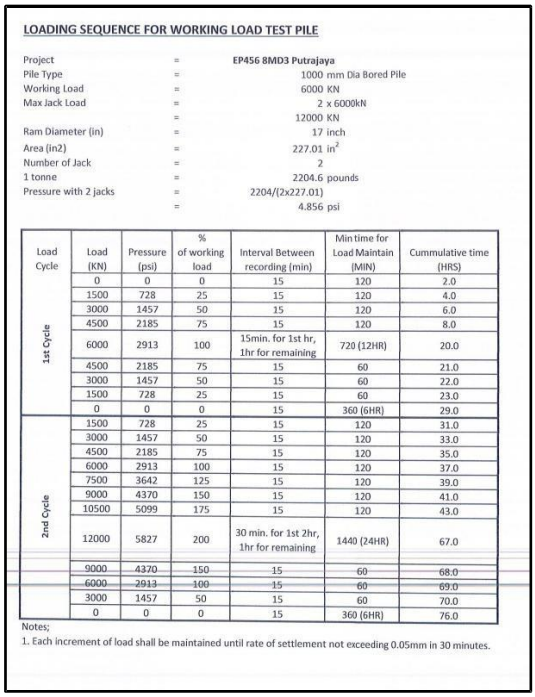
Next, the Pile Dimensions data is gathered. This comprises the simulated piles' diameter, length, form, and cross-sectional area. These measurements are necessary to establish the geometry of the pile in the model, which influences how the pile reacts under stress.

Table 1 : Precast Concrete Piles Parameter

Precast Concrete Piles Parameter						
Y unsat (kN/m³)	Y sat (kN/m³)	E reff (kN/m²)	V (nu)	Cohension (kN/m²)	Friction angel	Model
24	24	3.0 x 10^7	0.1	-	-	Linear Elastic
24	24	2.35 x 10^7	0.2	500	35	Linear Elastic
24	-	24500 x 10^3	0.2	-	-	Linear Elastic

Following that, Maintained Load Test Records are compiled. These data provide genuine field performance statistics for piles under sustained load. The test results aid in verifying the simulation model and act as a benchmark to guarantee that the simulation performs properly in comparison to field settings.

All of this collected data is required to create a dependable and accurate model for further simulation and analysis. The thoroughness and quality of this phase have a direct impact on the trustworthiness of the findings in subsequent phases of the study.



LOADING SEQUENCE FOR WORKING LOAD TEST PILE

Project = EP456 8MD3 Putrajaya
Pile Type = 1000 mm Dia Bored Pile
Working Load = 6000 KN
Max Jack Load = 2 x 6000kN
= 12000 KN
Ram Diameter (in) = 17 inch
Area (in2) = 227.01 in^2
Number of Jack = 2
1 tonne = 2204.6 pounds
Pressure with 2 jacks = 2204/(2x227.01)
= 4.856 psi

Load Cycle	Load (KN)	Pressure (psi)	% of working load	Interval Between recording (min)	Min time for Load Maintain (MIN)	Cummulative time (HRS)
1st Cycle	0	0	0	15	120	2.0
	1500	728	25	15	120	4.0
	3000	1457	50	15	120	6.0
	4500	2185	75	15	120	8.0
	6000	2913	100	15min. for 1st hr, 1hr for remaining	720 (12HR)	20.0
	4500	2185	75	15	60	21.0
	3000	1457	50	15	60	22.0
	1500	728	25	15	60	23.0
	0	0	0	15	360 (6HR)	29.0
2nd Cycle	1500	728	25	15	120	31.0
	3000	1457	50	15	120	33.0
	4500	2185	75	15	120	35.0
	6000	2913	100	15	120	37.0
	7500	3642	125	15	120	39.0
	9000	4370	150	15	120	41.0
	10500	5099	175	15	120	43.0
	12000	5827	200	30 min. for 1st 2hr, 1hr for remaining	1440 (24HR)	67.0
	9000	4370	150	15	60	68.0
	6000	2913	100	15	60	69.0
	3000	1457	50	15	60	70.0
	0	0	0	15	360 (6HR)	76.0

Notes;
1. Each increment of load shall be maintained until rate of settlement not exceeding 0.05mm in 30 minutes.

Figure 3 : Maintained Load Test Record

2.2Data Analysis Method

The stability performance of precast concrete piles (PCP) and geopolymer concrete piles (GPCP) is investigated using PLAXIS 2D simulations. The models were built using conventional geometry and material parameters to investigate how each pile type performs under various loading circumstances. The primary goal is to assess and compare their loadbearing capability, deformation behaviour, and overall structural performance.

Load-settlement curves, deformation behaviour, and safety aspects are among the most significant findings. These results assist determine how successfully each pile type distributes load to the earth, how much it settles under load, and if it remains stable within permissible limitations. This offers information on both the strength (axial capacity) and serviceability of the two materials.

The research is based on incremental loads of up to 12000 kN, applied equally to both pile types. Settlement, stress, and deformation are recorded at each stage to guarantee fair comparison. Because shape and boundary conditions are consistent, any performance discrepancies may be attributable only to material attributes.

Data is given as graphs (e.g., load vs. settlement) and tables to facilitate comparisons. The findings show variations in stiffness and stress management at the pile-soil interface, particularly in sandy silt soil, which is frequent in practice. The data assist to establish if geopolymer piles may be a sustainable and effective alternative to typical precast concrete piles.

3.0 RESULT AND ANALYSIS

The findings from PLAXIS 2D simulations used to assess and compare the stability performance of precast concrete piles (PCP) and geopolymer concrete piles (GPCP) under various axial loading circumstances. The study focuses on the load-settlement behaviour, displacement patterns, and overall structural response of a standardized sandy soil profile. By simulating two pile types with similar geometries and boundary conditions, the study ensures a fair comparison in which performance variations are exclusively due to material attributes. The results are examined in terms of their significance for foundation design, sustainability, and the prospective use of geopolymer concrete as an ecologically benign alternative in pile foundations.

3.1Design Model Using Plaxis 2D

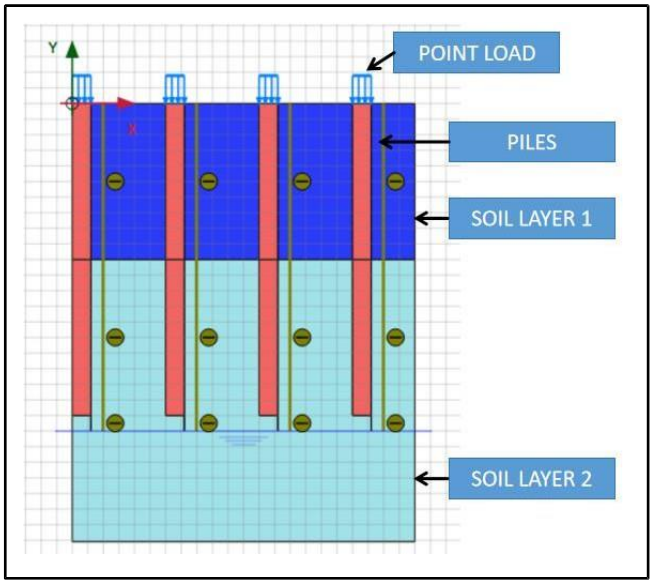


Figure 4 : Soil Structure Design in Plaxis 2D

As shows in figure 4, this design employed PLAXIS 2D software to simulate the behaviour of precast and geopolymer concrete piles under load in sandy silt soil. The model comprises two separate soil layers based on site research data, each with its unique strength and stiffness parameters that influence how the soil reacts to loads. Vertical piles constructed of conventional or geopolymer concrete are put within these layers, with a point load supplied to the top of each pile to imitate construction loads.

The model is configured on a two-dimensional plane with specified bounds to avoid undesired movement and assure precise results. This configuration enables the measurement of settlement and deformation when loads are applied. By applying the identical circumstances to both pile types, the model gives a fair assessment of their performance, providing important insights on their stability and appropriateness for foundation applications.

3.2 Data Output From Plaxis 2D

Table 2 : Data Output from Plaxis 2D for Precast Concrete Pile

PRECAST CONCRETE PILE					
MODEL	STAGE	LOAD (kN)	MIN SETTLEMENT (mm) - Uy	MIN DEFORMATION (mm) -Ux	FOS
	Loading Stage	0	0.00273	4.34E-04	2.7320
		1500	3.397	0.1908	2.638
		3000	8.454	0.2090	2.526
		4500	18.10	0.2145	2.4970
		6000	19.37	0.2316	2.421
		7500	23.11	0.7400	2.3760
		9000	55.5	1.594	2.155
		10500	59.64	1.916	1.975
		12000	60.64	3.335	1.894

This table 2 shows the simulation results from PLAXIS 2D for a precast concrete pile on sandy silt soil with increasing vertical loads ranging from 0 kN to 12000 kN. Vertical settlement (Uy), horizontal deformation (Ux), and the factor of safety (FOS) are all important outcomes. As the load rose, both vertical and horizontal deformations developed gradually, with little movement at lower values. However, at 7500 kN, settlement rose dramatically from 23.11 mm to 55.5 mm at 9000 kN indicating a non-linear reaction and the possibility of flexible soil behaviour.

Horizontal deformation remained very minor but increased substantially with larger loads, indicating some lateral displacement or pile bending under stress. At the same time, the FOS declined steadily from 2.7320 at the lowest load to 1.894 at 12000 kN, indicating a loss of safety margin as the pile approached its load capacity. Overall, the findings emphasize the need of considering soil structure interaction and nonlinear behaviour when building pile foundations in sandy silt settings.

Table 3 : Data Output from Plaxis 2D for geopolymer Concrete Pile

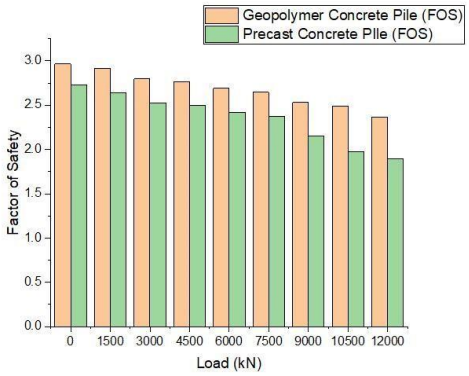
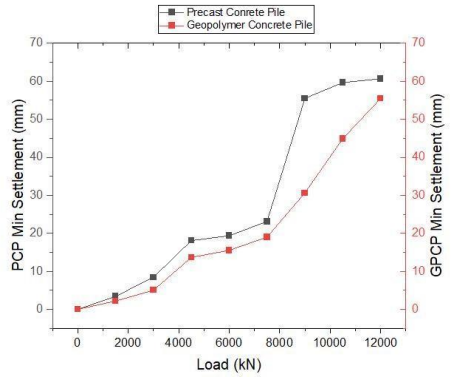
GEOPOLYMER CONCRETE PILE					
MODEL	STAGE	LOAD (kN)	MIN SETTLEMENT (mm) - Uy	MIN DEFORMATION (mm) -Ux	FOS
	Loading Stage	0	0.00144	2.29E-04	2.966
		1500	2.197	0.01834	2.912
		3000	5.039	0.02001	2.798
		4500	13.67	0.3034	2.767
		6000	15.52	0.7074	2.69
		7500	19.02	0.8859	2.645
		9000	30.63	1.691	2.529
		10500	44.89	1.915	2.488
		12000	55.46	1.976	2.363

Table 3 shows the performance of a geopolymer concrete pile (GPCP) on sandy silt soil is investigated using PLAXIS 2D under increasing vertical loads. The data contains applied load, vertical settlement (Uy), horizontal displacement (Ux), and Factor of Safety (FOS), with loads rising gradually from 0 kN to 12000 kN. As the weight rose, vertical and horizontal motions increased progressively. Beyond 7500 kN, settlement increased significantly, reaching 30.63 mm at 9000 kN, indicating a nonlinear reaction and potential deterioration in soil stiffness.

Horizontal deformation remained modest but increased with larger loads, indicating a minor lateral displacement. At the same time, the Factor of Safety (FOS) fell from 2.966 to 2.363, indicating a progressive reduction in safety margin. These findings emphasize the high load capacity of GPCP as well as the need of considering soil-structure interaction.

3.3 GRAPH ANALYSIS OF DATA OUTPUT FROM PLAXIS 2D

Table 4 : Graph Analysis between Precast Concrete Pile and Geopolymer Concrete Pile

Section	Result	
Factor of Safety		This bar chart compares the Factor of Safety (FOS) for Precast and Geopolymer Concrete Piles in sandy silt soil with increasing load. Geopolymer piles regularly have higher FOS levels, suggesting greater stability and load resistance. They exhibit higher stiffness at early loading (0-4500 kN). As loads increase (6000-9000 kN), FOS drops for both, although Geopolymer Piles maintain a little edge. At 12000 kN, their FOS is much greater (2.363 vs. 1.894), indicating better performance in harsh situations.
Minimum Settlement		This graph compares the settling of precast concrete piles (PCP) with geopolymer concrete piles (GPCP) in sandy silt soil as loads increase. Up to 6000 kN, both piles exhibit low and comparable settling, with GPCP performing somewhat better. As stresses rise, PCP settles more quickly, indicating less stiffness. At 9000 kN, PCP settles 55.5 mm, whereas GPCP settles 30.63 mm. At 12000 kN, PCP achieves 60.64 mm and GPCP 55.46 mm, demonstrating GPCP's higher stability and load transfer efficiency.

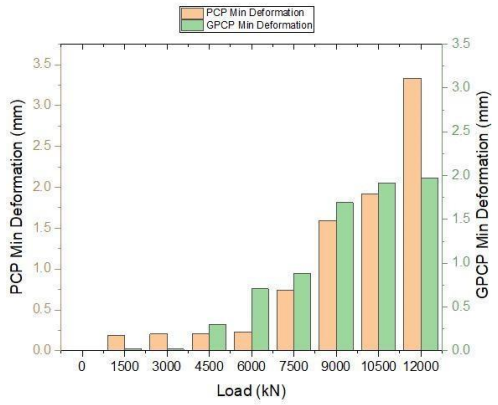
Minimum Deformation		This graph compares the horizontal deformation (Ux) of Precast Concrete Piles (PCP) and Geopolymer Concrete Piles (GPCP) in sandy silt soil with increasing load. In the early phases (0-4500 kN), both exhibit negligible deformation, with GPCP performing better. As stresses grow (6000-9000 kN), PCP exhibits increased lateral movement, indicating a decrease in stiffness. At 12000 kN, PCP deforms 3.34 mm, but GPCP deforms just 1.98 mm, indicating that GPCP has superior lateral stability and stiffness at high loads.

Table 4 shows comparison of Precast Concrete Piles (PCP) to Geopolymer Concrete Piles (GPCP) based on Factor of Safety, settling, and deformation under increasing loads in sandy-silt soil. GPCP routinely outperforms, with greater safety factors, particularly at higher loads (2.363 versus 1.894 at 12000 kN). It also settles less than PCP, with a significant advantage at 9000 kN (30.63 mm vs. 55.5 mm), indicating superior load transmission. While both piles distort somewhat at initially, GPCP has greater lateral stability under high loads. Overall, GPCP provides a safer and more efficient foundation choice.

5.0 CONCLUSION

This study investigated the stability performance of Precast Concrete Piles (PCP) and Geopolymer Concrete Piles (GPCP) in sandy silt soil using PLAXIS 2D finite element simulations. Driven by the crucial need for sustainable building practices in foundation engineering, the study sought to assess geopolymer concrete as an environmentally friendly alternative to standard OPC-based concrete, which has a high carbon footprint. By rigorously investigating load-settlement response, horizontal deformation, and Factor of Safety (FOS) under incremental axial loads, this study gives useful insights on GPCP structural efficiency and environmental benefits.

The simulation results consistently showed that Geopolymer Concrete Piles outperformed Precast Concrete Piles in terms of stability over a wide range of stress circumstances. Specifically, GPCPs had a higher Factor of Safety throughout all loading phases, indicating a larger margin of safety and reserve capacity. Furthermore, whereas both pile types exhibited increased settlement and horizontal deformation with larger loads, Geopolymer Concrete Piles consistently demonstrated less vertical settlement and much less horizontal distortion, especially under extreme loading circumstances. This suggests that GPCPs have increased stiffness and improved load-transfer efficiency in sandy silt soil, resulting in more stable and efficient load-bearing capacities.

Lastly, the data clearly suggest geopolymer concrete as a structurally sound and environmentally friendly alternative to pile foundations. Geopolymer Concrete Piles offer superior performance in terms of settlement, deformation, and Factor of Safety, as well as environmental benefits (lower CO_2 emissions from industrial by-products), making them a promising solution for modern geotechnical engineering. This study provides critical factual data to help bridge the knowledge gap on geopolymer concrete in foundation applications, supporting greater usage and standardization to promote global sustainability goals in the building sector.

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CountMe: An Intelligent Mobile Solution for Real-Time Traffic Flow Monitoring

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ABSTRACT

The rapid growth of urban areas and the increasing number of vehicles have posed significant challenges to efficient traffic monitoring. Traditional methods, such as manual vehicle counting, are becoming obsolete due to high labour demands, time consumption, and a high risk of error caused by fatigue and adverse weather conditions. This study aims to develop CountMe, a smart mobile application designed to automate real-time vehicle counting using a standard smartphone. The study was conducted along Jalan A183, Taman Tasek Indra, Ipoh, Perak, focusing on high-traffic intersections near commercial zones. The scope includes video-based traffic recording, vehicle flow analysis, and impact assessment for urban infrastructure planning. Findings from surveys and Q&A sessions with 30 traffic engineers and professionals revealed strong acceptance of the application. The application demonstrated an average detection accuracy exceeding 93% for both video and live detection modes. Additionally, results from the Paired Samples T-Test reported an average mean score of 3.83, indicating that users rated the application's effectiveness significantly higher than traditional manual methods. The implementation of CountMe offers numerous advantages, including reduced manpower dependency, real-time monitoring capabilities, and consistent, accurate traffic data. This study supports the adoption of intelligent mobile solutions to enhance urban traffic management and contribute to the development of smarter, more sustainable cities.

Keywords: smart mobility, auto counting, edge analytics, traffic vision, urban intel

1.0 INTRODUCTION

The transportation sector in Malaysia faces increasing pressure due to rapid urbanization, rising vehicle ownership, and traffic congestion in major cities (Musa et al., 2023). Traditional traffic monitoring systems, particularly manual vehicle counting, continue to be widely used, despite being inefficient, time-consuming, and error-prone. As urban traffic networks grow in complexity, these conventional approaches no longer meet the precision and scalability required for effective traffic engineering. Studies have shown that manual counting methods often result in inaccurate data, especially under high-volume or low-visibility conditions, leading to suboptimal planning decisions (Al-qaness et al., 2021).

Technological advancements under the Fourth Industrial Revolution (IR 4.0) offer promising alternatives through the integration of mobile computing, artificial intelligence (AI), and realtime video processing. Mobile-based applications enable traffic data collection to be carried out directly on smartphones, reducing the need for costly fixed sensors or large-scale infrastructure (MITI, 2018). These tools empower traffic authorities and city planners to gather and analyze vehicle flow data efficiently while promoting paperless operations and enhancing environmental sustainability, in line with Sustainable Development Goals (United Nations, 2023).

In practice, most vehicle data is still collected using manual counters or CCTV reviews, which introduces significant delays and human-dependent inefficiencies. Aim of this study is to develop an innovative application that can simplify the vehicle counting process through video recordings, using the latest technology to ensure accuracy and efficiency in traffic data collection. The

limitations by introducing CountMe, a smart mobile application designed to automate the vehicle counting process using real-time video input. The application not only simplifies the data collection process but also allows for automatic conversion of vehicle types into Passenger Car Units (PCU), enabling direct use in traffic analysis. Objective of this study Commented [u1]: Objectives of this study are are to identify problems related to the vehicle calculation method, to innovate a smart application that automates vehicle counting using video recordings, and to evaluate the effectiveness of the application automates vehicle counting using video recordings

2.0 METHODOLOGY

Figure 1 illustrates the overall methodology used in the development of the CountMe application, divided into three main phases, Phase 1 (Problem Identification and Concept Design), Phase 2 (Product Development and Testing), and Phase 3 (Analysis and Recommendations).

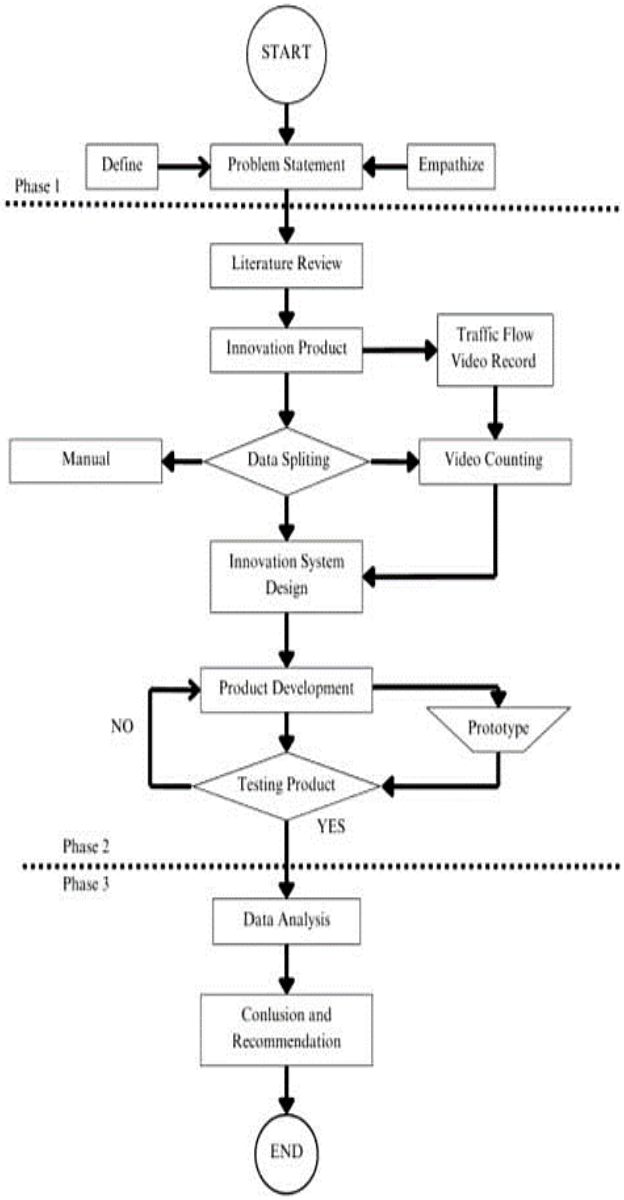

Figure 1: overview methodology

The process begins with identifying the core issue through two key activities define and empathize, which lead to the formulation of a clear problem statement. This is followed by a comprehensive Literature Review to assess existing solutions and identify technological gaps in current traffic counting methods.

Based on the findings, an Innovation Product is proposed. In parallel, real traffic flow video recordings are collected to support the design process. These recordings are used in the Video Counting stage, after which the collected data is split (Data Splitting) into two streams for analysis manual vehicle counting and system-based automated counting.

Next, an Innovation System Design process is carried out to develop the application logic and user interface. This transitions into the Product Development phase, where a working Prototype of the CountMe application is created. The prototype undergoes Product Testing to evaluate performance and reliability. If the prototype fails to meet the required standards, it loops back for further development. If successful, the methodology moves into Phase 3.

The CountMe application was developed using Android Studio as the primary platform for designing the user interface, implementing system logic, and enabling video-based vehicle counting. The core functionality of the application is centred around video input, which is used to manually interpret vehicle flow without relying on complex machine learning models. All collected data, including the number of detected vehicles and time-stamped records, is stored and synchronized using Firebase, a cloud-based platform that supports real-time database management and digital report generation. Users can export the results in PDF format, enabling easy documentation and further traffic analysis.

Figure 2 illustrates the CountMe application interface, which consists of four main screens: the welcome/start page, the live video input and detection screen, the PCU report entry form, and the final PCU result display. This intuitive layout was designed to ensure ease of use and quick navigation for traffic engineers and field users, supporting efficient data recording and report generation.

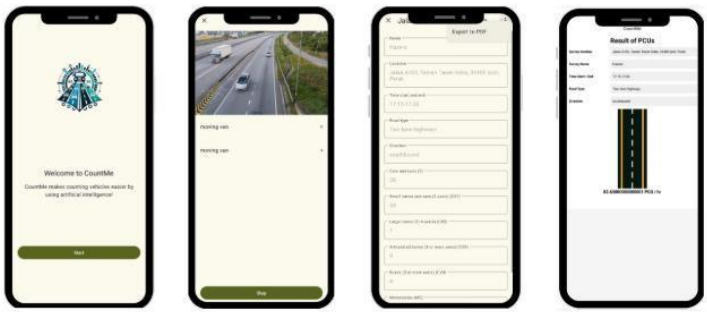

Figure 2: CountMe interface

In Phase 3, Data Analysis is performed using both technical results and user feedback to assess accuracy, efficiency, and usability. The study concludes with a final Conclusion and Recommendation based on all findings, marking the end of the development cycle. In the final phase, the CountMe application was evaluated through technical testing and structured user feedback involving 30 respondents, including traffic engineers, site supervisors, and civil engineering professionals. Participants tested the application under simulated field conditions and responded to a questionnaire measuring usability, accuracy, time efficiency, and satisfaction compared to manual counting methods. The collected data were processed and analyzed using SPSS software, with a Paired Sample T-Test conducted to assess the statistical significance of differences in user experience. Technical performance metrics such as detection

accuracy and PCU conversion consistency were also reviewed. The results indicated that the application is both effective and practical, with recommendations for further improvement including enhanced detection in low-light environments and better export functions for field reporting.

2.0 RESULT AND DISCUSSION

This section discusses the analysis results obtained through user surveys, system performance evaluations, and accuracy comparisons between the CountMe mobile application and conventional manual counting methods. Each table is elaborated to provide insight into how the application performed in various operational and technical criteria. The discussion also includes statistical validation and reliability testing to support the credibility of the findings.

Table 1: Respondent's Demography

		Count	Percentage
Gender	Male	19	64.50%
	Female	11	35.50%
Age	18-25	1	6.40%
	26-35	14	45.20%
	36-45	15	48.40%
	46 and above	0	0.00%
Designation	Traffic Engineer	3	12.90%
	Engineer	12	38.70%
	Traffic Management Officer	2	6.50%
	Road and Drainage Engineer	9	29.00%
	Assistant Engineer	4	12.90%
Work Experience	< 1 year	2	9.70%
	1-5 years	7	22.60%
	6-10 years	13	41.90%
	>10 years	8	25.80%

Table 1 show a breakdown of the respondents' demographics. The results show that a majority of the participants were male (64.5%) and within the age range of 36–45 years (48.4%), followed closely by those aged 26–35 (45.2%). Most respondents were general engineers (38.7%), road and drainage engineers (29.0%), or assistant engineers (12.9%). Regarding work experience, 41.9% had been in the field for 6–10 years, while 25.8% had more than 10 years of experience. These figures indicate that the feedback obtained came from highly experienced professionals, which strengthens the credibility of the evaluation (Pallant, 2020).

Table 2: Mean Score Interpretation Scale by EPRD (2006)

Mean Score Range	Interpretation
1.00 – 1.89	Very Low
1.90 – 2.69	Low
2.70 – 3.49	Moderate
3.50 – 4.29	High
4.30 – 5.00	Very High

Table 3: Comparison of Mean Scores Between CountMe Application and Manual Counting Method

Variables	CountMe Counting		Mean Score Manual Counting	
	Mean	Mean Score Interpretation Scale	Mean	Interpretation Scale
Ease of Use	4.2	High	1.87	Very Low
System Design	4.37	High	1.9	Low
Time Efficiency	4.47	High	1.63	Very Low
Data Accuracy	3.5	High	2.27	Moderate
Monitoring	4.2	High	2.13	Low
Implementation Cost	4.13	High	1.6	Very Low
Counting Method	4.1	High	1.97	Low
Sustainability	4.4	High	1.63	Very Low
Final Output	4.03	High	1.7	Very Low
Overall Effectiveness	4.13	High	2	Low
Average Mean	**4.15**	**High**	**1.87**	**Very Low**

Table 2 introduces the mean score interpretation scale from the Educational Planning and Research Division (EPRD), where scores are categorized from "Very Low" (1.00–1.89) to "Very High" (4.30–5.00). This scale ensures consistency in interpreting Likert-based survey responses (EPRD, 2006). Using this scale, Table 3 shows that CountMe achieved “High” scores across all variables, including time efficiency (4.47), system design (4.37), and overall effectiveness (4.13). In contrast, manual methods received mostly “Low” to “Very Low” scores—for instance, only 1.63 for time efficiency and 1.60 for implementation cost. These results highlight CountMe’s superior usability and functionality in real-world use.

Table 4: Paired Sample t-Test

No	Variable	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
1	Ease of Use	2.33	0.92	0.17	13.86	29.00	< 0.001
2	System Design	2.47	0.94	0.17	14.42	29.00	< 0.001
3	Time Efficiency	2.83	0.83	0.15	18.61	29.00	< 0.001
4	Data Accuracy	1.23	1.83	0.33	3.69	29.00	< 0.001
5	Monitoring	2.07	1.14	0.21	9.91	29.00	< 0.001
6	Implementat ion Cost	2.53	1.07	0.2	9.41	29.00	< 0.001
7	Counting Method	2.43	1.07	0.2	10.28	29.00	< 0.001
8	Sustainabilit y	2.77	0.94	0.17	16.20	29.00	< 0.001
9	Final Output	2.33	1.12	0.21	11.37	29.00	< 0.001
10	Overall Effectivenes s	2.13	1.2	0.22	9.77	29.00	< 0.001
11	Average	2.32	0.72	0.13	0.779	29	< 0.001

Table 4 presents the results of the paired sample t-test conducted to validate the statistical difference between the performance of CountMe and the manual method. All ten variables showed statistically significant differences, with p-values less than 0.001. The time efficiency variable recorded a t-value of 18.61, one of the highest, clearly indicating a significant improvement with CountMe. Other variables like system design (t = 14.42) and final output (t = 11.37) further emphasize the considerable gap in user satisfaction and performance between the two methods. These results statistically confirm that the CountMe application provides a superior experience and operational advantage. Pallant (2020) recommends the use of paired t-tests in system comparisons where the same participants evaluate both systems, ensuring internal validity.

Table 5: Cronbach's Alpha Interpretation Guidelines (George & Mallery, 2003)

Cronbach's Alpha (α) Range	Interpretation
$\alpha \geq 0.90$	Excellent
$0.80 \leq \alpha < 0.90$	Good
$0.70 \leq \alpha < 0.80$	Acceptable
$0.60 \leq \alpha < 0.70$	Questionable
$0.50 \leq \alpha < 0.60$	Poor
$\alpha < 0.50$	Unacceptable

Table 6: Reliability Statistics for CountMe Mobile Application Questionnaire

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.692	0.715	10

Table 5 show the internal consistency of the instrument used to measure user feedback using Cronbach's Alpha. The value obtained was 0.692, which falls into the "acceptable" category according to George and Mallery (2010), especially for exploratory studies and early-stage system evaluations. This suggests that the survey items used to assess CountMe's performance were adequately reliable and that the responses can be considered consistent across multiple users. Such reliability is crucial in ensuring that the evaluation data reflects genuine user experiences rather than measurement bias.

The CountMe mobile application received positive responses from 30 professionals in the traffic field, most of whom had significant work experience. This lends credibility to the evaluation results (Pallant, 2020). The application demonstrated high performance in key areas such as ease of use, time efficiency, accuracy, and cost-effectiveness, with average scores above 4.0 based on the EPRD interpretation scale (EPRD, 2006). In contrast, traditional manual counting methods received low to very low scores across the same categories. Statistical analysis using a Paired

Sample T-Test showed significant differences between CountMe and manual methods, with all p-values < 0.001. The highest t-value was recorded for time efficiency (t = 18.61), highlighting CountMe's superior speed and functionality (Pallant, 2020). Additionally, reliability analysis using Cronbach's Alpha produced a score of 0.692, categorized as "acceptable," which indicates that the survey instrument was consistent and reliable (George & Mallery, 2003).

3.0 CONCLUSION

In conclusion, the development of the CountMe application has successfully proven its potential as a smart and cost-effective solution for real-time vehicle counting. Compared to conventional manual methods, CountMe offers improved speed, accuracy, and efficiency, making it highly suitable for urban traffic monitoring and intelligent city planning. The system's performance reflects its relevance and practicality in supporting sustainable development, particularly in line with the objectives of SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 17 (Partnerships for the Goals).

For future improvements, several features are recommended to enhance user experience and data utility. These include more accurate object tracking, the ability to export traffic data directly to Excel for further analysis, and the integration of directional arrows in the PDF output for clearer traffic flow interpretation. These enhancements are aligned with the principles of Industry 4.0, incorporating elements of automation, data exchange, and smart analytics.

Overall, the CountMe application demonstrates a forward-looking approach to traffic data management, contributing positively to smarter, safer, and more efficient transportation systems.

ACKNOWLEDGMENT

Acknowledging the paramount contributions to this project, the author extends deep appreciation to Ms. Samikhah Binti Muhammad @ Munir, the esteemed project supervisor. Her unwavering support, expert guidance, and thoughtful encouragement were transformative, shaping both the direction and quality of this research. Her insights and dedication served as a driving force that inspired excellence throughout every stage of this work. A special acknowledgment is also extended to the team at Prima Reka Konsultan, whose collaboration and professional input were invaluable. Their commitment to sharing real-world insights and supporting data collection efforts significantly enriched the depth and relevance of this study. Their role was crucial in ensuring that the project aligned with current industry practices and standards. Together, their combined contributions laid the foundation for the successful completion of this research.

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Effectiveness of Metaheuristic Algorithms for Hyperparameter Tuning of Machine Learning Models in Predicting Spun Pile Efficiency

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ABSTRACT

This study proposes a hybrid modelling framework for predicting the efficiency of spun pile foundations by leveraging machine learning algorithms optimized through nature-inspired metaheuristic techniques. Utilizing a dataset comprising 150 Pile Driving Analyzer (PDA) test records, three predictive models were developed which is Adaptive Neuro-Fuzzy Inference System (ANFIS), Support Vector Machine (SVM), and Regression Tree (RT). Each model incorporates distinct functional structures, with ANFIS using generalized bell-shaped membership functions, SVM using a Gaussian radial basis function kernel, and RT using recursive binary splitting. To enhance model performance, hyperparameters were optimized using the Sparrow Search Algorithm (SSA), Whale Optimization Algorithm (WOA), and Manta Ray Foraging Optimization (MRFO). Performance evaluation was conducted using statistical indicators, where the ANFIS model optimized by SSA achieved superior predictive accuracy with RMX (RMSE = 0.123, R^2 = 1.000) and FMX (RMSE = 0.560, R^2 = 1.000). A MATLAB-based graphical user interface was also developed to facilitate real-time prediction of pile efficiency, providing a practical tool for engineering professionals. The findings underscore the potential of integrating machine learning with metaheuristic optimization as a cost-effective and reliable alternative to conventional pile testing methods, thereby contributing to safer and more efficient geotechnical engineering practices.

Keywords: Spun Pile Efficiency, ANFIS, SVM, RT, Metaheuristic Optimization, Sparrow Search Algorithm (SSA)

1.0 INTRODUCTION

Spun piles are prestressed hollow concrete foundation elements produced via a high-speed spinning process, which confers several notable advantages, including low permeability and high load-bearing capacity (Khatri, Sharma, & Awasthi, 2020). Low permeability minimizes fluid ingress, enhancing durability and resistance to environmental degradation, whereas high load-bearing capacity allows for supporting significant structural loads. These properties make spun piles particularly suitable for foundation applications in areas characterized by insufficient shallow soil conditions, such as soft or loose soils where traditional shallow footing methods are inadequate. In such contexts, deep foundations like spun piles provide stability and ensure the safety of structures.

Despite their advantages, only approximately 2.5 percent of total piles are typically subjected to Pile Driving Analyzer (PDA) testing owing to high costs and logistical challenges (Chowdhury, Islam, & Kabir, 2020). This limited testing regime introduces significant risks; notably, it reduces the representativeness of pile performance evaluations, potentially overlooking variances in pile behavior across different soil conditions or installation parameters. Consequently, decisions based solely on a small subset of field data may lead to inaccurate assessments of site safety and foundation reliability, increasing the risk of structural failure or over-conservatism that inflates construction costs.

Previous studies underscore the importance of accurate prediction models for pile performance. Techniques such as the ANFIS,SVM and RT have demonstrated higher accuracy in modelling complex, nonlinear relationships inherent in geotechnical data (Nguyen, Van, & Pham, 2021). These models are capable of capturing intricate patterns in PDA records such as hammer drop weight, pile segment length, penetration depth, ultimate depth mackintosh probe and set value and thus provide reliable predictions of pile efficiency parameters such as the maximum resistance (RMX) and maximum force (FMX).

Metaheuristic algorithms including the Sparrow Search Algorithm (SSA), Whale Optimization Algorithm (WOA), and Manta Ray Foraging Optimization (MRFO) have been employed to optimize the hyperparameters of these machine learning models. SSA mimics the social foraging behaviour of sparrows and balances exploration and exploitation to find optimal solutions (Zhang et al., 2021). WOA draws inspiration from bubble-net hunting strategies of whales and effectively navigates high-dimensional search spaces (Mirjalili & Lewis, 2016). MRFO emulates the foraging strategies of manta rays, fostering diversity within the search process and avoiding local minima (Shen et al., 2020). These algorithms significantly improve the robustness and predictive performance of machine learning models by efficiently tuning hyperparameters. However, there remains a gap in developing integrated systems that combine these advanced models with metaheuristic optimization within a practical, user-friendly environment.

The primary objectives of this study are to evaluate the effectiveness of metaheuristic optimization algorithms in enhancing the predictive performance of ANFIS, SVM, and RT models for pile efficiency estimation. Second, to develop a prototype prediction system based on the optimal machine learning model, integrating a user-friendly interface. Third, to validate the predictive performance of the developed prototype system in estimating pile efficiency, ensuring accuracy and alignment with industry standards for foundation engineering assessments.

By leveraging the combined strengths of machine learning and metaheuristic algorithms, this research aims to produce more reliable and cost-effective tools for foundation evaluation. Such systems can significantly reduce reliance on costly physical testing and enable more accurate assessments using existing datasets. Ultimately, this approach contributes to safer and more efficient foundation designs, benefiting practitioners and stakeholders in the geotechnical engineering community.

2.0 METHODOLOGY

This section delineates the comprehensive approach employed to develop and validate predictive models for assessing spun pile efficiency. The methodology encompasses data acquisition, pre-processing, model development, hyperparameter optimization, and system implementation within a systematic research framework. The integration of machine learning algorithms with metaheuristic optimization techniques is central to enhancing the predictive accuracy and robustness of the models, culminating in the development of a prototype prediction system with a user-friendly interface.

2.1 Research Framework Overview

The overarching research framework consists of five interrelated stages: data collection, data pre-processing, model development, optimization, and system implementation, as illustrated in Figure 1.

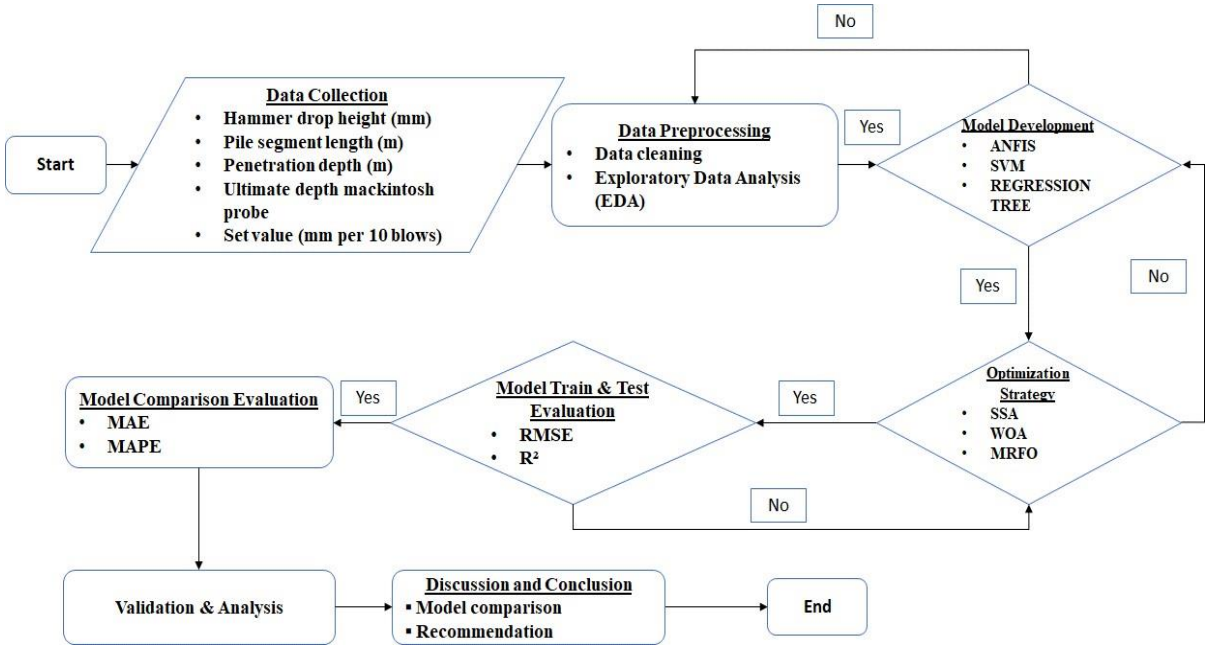

Figure 1: Research Methodology Flowchart

In the initial stage show in table 1, comprehensive historical PDA test data are collected from a local construction firm. These data sets include a range of parameters associated with pile driving and installation processes. The collected variables are essential for accurately modelling pile behaviour and assessing performance under field conditions.

Table 1: Data Range (Minimum and Maximum Values) for Database Computation

Feature	Minimum Value	Maxmimum Value
Hammer Drop Height (mm)	450	800
Pile Segment Length (m)	12	30
Penetration Depth (m)	5	29.9
Ultimate Depth Mackintosh Probe (reach 400 blows)	4.3	10.9
Set Value (mm per 10 blows)	2	14

Following data collection, preprocessing procedures are carried out to ensure the quality and reliability of the input data. This stage involves handling missing values, normalizing the feature set, and identifying and removing outliers. These steps are critical to ensuring that the data are consistent and suitable for subsequent machine learning modeling.

In the model development stage, three supervised machine learning techniques are employed which is ANFIS, SVM and RT. These models are constructed to predict two key performance indicators of pile efficiency that were the maximum resistive force during pile driving and the maximum force experienced by the pile. Both indicators serve as quantitative measures of structural integrity and installation quality.

To enhance the predictive performance and generalization capability of the models, hyperparameter tuning is conducted using three state-of-the-art metaheuristic optimization algorithms which is SSA, WOA and MRFO. These algorithms systematically explore the hyperparameter space to identify optimal configurations that minimize prediction error and improve model robustness.

In the final stage, the optimized models are deployed within a graphical user interface developed using MATLAB App Designer. This user-friendly interface allows practitioners to input relevant pile parameters and obtain real-time predictions of pile performance. The integrated system aims to support efficient and accurate decision-making in geotechnical engineering applications by reducing reliance on extensive physical testing.

2.2 Model Development

This phase focused on constructing reliable predictive models to estimate pile efficiency parameters using the pre-processed PDA data. The selection of modelling techniques was guided by their demonstrated effectiveness in capturing complex, nonlinear patterns commonly encountered in geotechnical engineering datasets.

Three machine learning algorithms were employed in this study. Each algorithm offers distinct advantages in terms of learning capacity, interpretability, and suitability for engineering applications.

The ANFIS model integrates the learning capabilities of artificial neural networks with the reasoning structure of fuzzy logic systems. This hybrid architecture enables the model to approximate nonlinear mappings between input and output variables with considerable flexibility and adaptability.

The SVM algorithm is well-suited for regression tasks involving high-dimensional feature spaces. By employing kernel functions, SVM transforms input data into higher-dimensional representations, allowing for more effective separation and regression modelling. Its ability to generalize well to unseen data makes it particularly valuable for predictive applications in variable field conditions.

The RT model was selected for its simplicity and interpretability. RT constructs decision paths based on input features through recursive binary splitting, resulting in a tree-like structure that is easy to interpret and computationally efficient. This makes it suitable for practical applications where transparency and ease of understanding are essential.

Initial versions of all models were trained using default hyperparameter configurations to establish baseline performance. Following this, hyperparameters specific to each model were systematically optimized. For ANFIS, this included tuning the number and type of membership functions. In SVM, key parameters such as kernel type, regularization coefficient, and epsilon value were adjusted. For RT, parameters such as maximum tree depth, minimum samples per leaf, and splitting criteria were optimized.

The objective of this iterative optimization process was to enhance each model's predictive accuracy and robustness, ensuring reliable performance in estimating the maximum resistive force (RMX) and maximum force (FMX) experienced by piles during installation.

2.3 Optimization Strategy

The optimization strategy employed in this study was designed to systematically enhance the predictive accuracy and generalization capability of the machine learning models through rigorous hyperparameter tuning. Hyperparameters, which govern the internal functioning of models such as ANFIS, SVM and RT, significantly influence model performance. For example, in the case of ANFIS, hyperparameters include the number and type of membership functions; for SVM, critical parameters include kernel type and regularization coefficient; and for RT, relevant parameters include maximum tree depth and the choice of splitting criteria. To ensure optimal model performance, these hyperparameters were selected within predefined value ranges, as outlined in Table 2.

Table 2: Hyperparameter Ranges for Machine Learning Models

Model	Hyperparameter	Range/Options
ANFIS	Number of Membership Functions	3 - 5
	Type of Membership Function	Triangular, Trapezoidal, Gaussian, Generalized Bell- Shaped, and Sigmoid Functions.
	Training Epochs	20 - 100
SVM	Kernel Type	Linear, Polynomial, RBF
	Regularization Parameter (C)	0.1 – 100
	Epsilon (ε)	0.001 – 0.1
RT	Maximum Tree Depth	2 – 20
	Minimum Samples per Leaf	1 – 10
	Splitting Criterion	Gini, Entropy, MSE

Manual hyperparameter tuning often leads to suboptimal solutions due to the complex, high dimensional search spaces involved. Therefore, an automated and systematic optimization approach was adopted. Three metaheuristic algorithms were utilized to identify optimal hyperparameter configurations: Sparrow Search Algorithm (SSA), Whale Optimization Algorithm (WOA), and Manta Ray Foraging Optimization (MRFO). These algorithms are well-regarded for their ability to perform global search, avoid premature convergence to local optima, and adapt to various optimization landscapes effectively.

Table 3: Metaheuristic Algorithm Parameter Ranges

Algorithm	Parameter	Range
SSA	Number of Sparrows	20 – 50
	Discover Rate Threshold	0.6 – 0.9
	Safety Threshold	0.1 – 0.3
	Maximum Iterations	50 – 200
WOA	Number of Search Agents	20 – 50
	A (Exploitation–Exploration Factor)	0.5 – 2
	Spiral Constant (b)	0.5 – 2
	Maximum Iterations	50 – 200
MRFO	Population Size	20 – 50
	Foraging Iterations	50 – 200
	Chain Foraging Probability (β)	0.1 – 0.9

The search ranges for the hyperparameters associated with each algorithm are summarized in Table 3. For SSA, parameters such as the number of sparrows and the discover and safety thresholds were tuned within specific limits. In the case of WOA, parameters including the number of search agents and the factors that balance exploration and exploitation were explored. For MRFO, population size and limits on foraging iterations were optimized.

The optimization process was guided by a fitness function incorporating multiple statistical evaluation metrics like Root Mean Square Error (RMSE) and the coefficient of determination (R^2) for ML models. Beside, Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) for Metaheuristic Algorithm. These metrics were used to quantify the deviation between the model predictions and the actual observed values, enabling the identification of hyperparameter configurations that minimized predictive error.

Each optimization procedure involved repeated cycles of training and testing the machine learning models with varying hyperparameter sets. The search continued until a predefined stopping criterion was met, which occurred either when the fitness function values converged or when the maximum number of iterations was reached. The configuration that yielded the best performance on validation data was ultimately selected as the optimal hyperparameter set.

By integrating machine learning algorithms with advanced metaheuristic optimization techniques, this study implemented a data-driven and computationally efficient hyperparameter tuning process. The optimized models achieved improved predictive accuracy, robustness, and generalizability in estimating spun pile efficiency based on PDA test data.

3.0 RESULTS AND DISCUSSION

This section presents the outcomes of the predictive modelling process, including the performance of ANFIS, SVM, and RT models before and after optimization using SSA, WOA, and MRFO algorithms. The evaluation employed several statistical metrics, including Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and the coefficient of determination (R^2), to comprehensively assess predictive accuracy and model robustness. The findings are contextualized within existing literature, emphasizing the improvement in model performance attributable to optimization and their potential applicability in geotechnical engineering practice.

3.1 Determination of Optimal Model Architectures for Pile Efficiency Prediction

This subsection presents the finalized analysis conducted to identify the most suitable model architectures for predicting pile efficiency using ANFIS, SVM and RT approaches. The study compared multiple model configurations before and after hyperparameter tuning, aiming to determine the optimal structure for each method based on predictive accuracy and statistical performance metrics.

For the ANFIS model, the configuration that yielded the best performance utilized triangular membership functions (Trimf) with a structure of five inputs and five membership functions per input (denoted as 5-5-5-5-5). This architecture achieved exceptional predictive results with a Root Mean Square Error (RMSE) of 0.21 and coefficient of determination (R^2) of 1.00 for RMX prediction. Similarly, the FMX prediction under the same configuration recorded an RMSE of 0.85 and R^2 of 1.00, indicating perfect fit and minimal prediction error.

In the case of the SVM model, various kernel types and optimization strategies were tested. The best configuration for RMX prediction was achieved using the Optimizable SVM with Bayesian optimization. This setup attained an RMSE of 154.31 and an R^2 value of 0.63. For FMX prediction, the optimal performance was delivered by the Fine Gaussian SVM with Principal Component Analysis (PCA), which resulted in an RMSE of 171.39 and R^2 of 0.54. The Bayesian optimization was also applied in hyperparameter tuning, allowing the model to identify suitable values for the regularization coefficient (C) and epsilon parameter.

For the RT model, extensive testing of tree structures and optimization techniques was conducted. The optimal architecture for RMX prediction was the Fine Tree model with PCA and hyperparameter tuning via Bayesian, Grid Search, and Random Search methods, all yielding consistent performance metrics with an RMSE of 155.18 and R^2 of 0.62. For FMX prediction, however, the model showed limited predictive strength. The best result was obtained using the Optimizable Tree with Grid Search, which achieved an RMSE of 574.09 and R^2 of 0.11, indicating weak correlation and high variance in predictions.

The comprehensive analysis concluded that hyperparameter optimization played a critical role in enhancing the performance of all models, particularly for RMX prediction. Among the three algorithms, ANFIS demonstrated superior predictive capability for both RMX and FMX, while SVM offered moderately strong results. In contrast, RT models, despite their interpretability, exhibited limited accuracy in FMX prediction. These findings underscore the importance of rigorous model architecture selection and tuning in the development of reliable machine learning tools for geotechnical applications.

3.2 Model Performance (Pre-Optimization vs Post-Optimization)

The comparative performance of the three machine learning models, namely ANFIS, SVM, and RT, was evaluated based on two output variables, RMX and FMX. The assessment was conducted before and after optimization using three selected meta-heuristic algorithms: Sparrow Search Algorithm (SSA), Whale Optimization Algorithm (WOA), and Manta Ray Foraging Optimization (MRFO). Table 2, Table 3, and Table 4 presents a summary of the performance in terms of Root Mean Square Error (RMSE) and the coefficient of determination (R^2).

Table 4: Performance of ANFIS Models Before and After Optimization for RMX and FMX Output.

Output	Model Performance	Hybrid	SSA	WOA	MRFO
RMX	RMSE	0.21	0.123	0.256	0.207
	R^2	1	1	1	1
FMX	RMSE	0.85	0.506	1.070	0.822
	R^2	1	1	1	1

In the case of the ANFIS model show in Table 4, notable improvements were observed following the optimization process. For the RMX output, the unoptimized (hybrid) model produced an RMSE of 0.210. SSA achieved the best performance, reducing the RMSE to 0.123. MRFO also improved the model's accuracy with an RMSE of 0.207, while WOA yielded a slightly higher error of 0.256. The higher RMSE values observed in the WOA-ANFIS model are primarily due to the stochastic nature of the WOA, which despite its strong global search capability, can sometimes prematurely converge or inadequately fine-tune hyperparameters, especially in complex models like ANFIS. Factors such as sensitivity to initial conditions, limited exploration due to early stopping, and the challenge of optimizing numerous model parameters may lead WOA to settle on suboptimal configurations, resulting in increased prediction errors. In contrast, other algorithms like SSA and MRFO, with different exploration exploitation balances, may have provided more effective hyperparameter searches under the same conditions, thereby achieving lower RMSE. All optimized ANFIS models reported an R^2 value of 1.000, indicating a near-perfect fit between predicted and actual values. For the FMX output, the hybrid ANFIS model recorded an RMSE of 0.850. SSA once again outperformed the other algorithms, reducing the RMSE to 0.506. MRFO provided moderate improvement (RMSE = 0.822), whereas WOA resulted in a higher error (RMSE = 1.070). Similar to the RMX output, all ANFIS configurations maintained an R^2 value of 1.000.

Table 5: Performance of SVM Models Before and After Optimization for RMX and FMX Output.

Output	Model Performance	Optimizer	SSA	WOA	MRFO
RMX	RMSE	154.31	147.52	147.46	147.46
	R^2	0.63	0.66	0.66	0.66
FMX	RMSE	171.39	133.93	606.620	564.41
	R^2	0.54	0.13	-0.02	0.13

Table 5 presents the performance metrics for the SVM models prior to and following optimization with different metaheuristic algorithms. The baseline SVM model exhibited moderate predictive accuracy, with Root Mean Square Error (RMSE) values of 154.31 for RMX and 171.39 for FMX, indicating considerable deviations from observed values, particularly for FMX, where the high RMSE suggests significant prediction errors. Post optimization, SSA achieved notable improvements, reducing RMSE to 147.52 for RMX and 133.93 for FMX, with corresponding R^2 values of 0.66 and 0.13, reflecting enhanced model fit, especially for RMX. However, optimization with WOA and MRFO did not yield substantial benefits that RMSE values remained around 147 for RMX but remained disproportionately high for FMX, exceeding 606, which indicates extreme prediction errors. The R^2 value for WOA in FMX fell below zero, implying that the model's predictions were inferior to simply predicting the mean of the observed data, highlighting poor generalization and reliability. The excessively high RMSE for FMX suggests potential overfitting, model instability, or inappropriate hyperparameter configurations, undermining the model's predictive robustness for this variable.

Table 6: Performance of RT Models Before and After Optimization for RMX and FMX Output.

Output	Model Performance	Leaf Size	SSA	WOA	MRFO
RMX	RMSE	155.18	90.37	90.37	105.45
	R^2	0.62	0.87	0.87	0.82
FMX	RMSE	574.09	370.88	370.88	370.88
	R^2	0.11	0.62	0.62	0.62

Table 6 illustrates the performance of the RT model before and after optimization using various meta-heuristic algorithms. The unoptimized RT model achieved an RMSE of 155.18 and an R^2 of 0.62 for the RMX output, indicating moderate predictive accuracy. After applying optimization techniques, both SSA and WOA reduced the RMSE to 90.37 and improved the R^2 values to 0.87, reflecting substantial enhancements in model accuracy and fit. The MRFO algorithm further improved the RMSE to 105.45, with R^2 increasing accordingly. For the FMX output, the unoptimized model demonstrated an RMSE of 574.09 and an R^2 of 0.11, signifying limited predictive capability. Post-optimization, the RMSE decreased to 370.88 across all three algorithms, and the R^2 value increased to 0.62, indicating significant improvements in the model's predictive performance. These results suggest that meta-heuristic tuning markedly benefits the RT model, particularly in predicting FMX.

Overall, the findings demonstrate that optimization enhances the predictive performance of all models. ANFIS, especially when optimized with SSA, consistently provided the most accurate and stable results for both RMX and FMX. While the SVM showed some improvement for RMX, its accuracy for FMX remained limited. Despite its relatively simple structure, the RT exhibited notable gains in predictive accuracy after optimization and presents as a practical alternative due to its lower computational complexity.

3.3 Performance Metrics Analysis

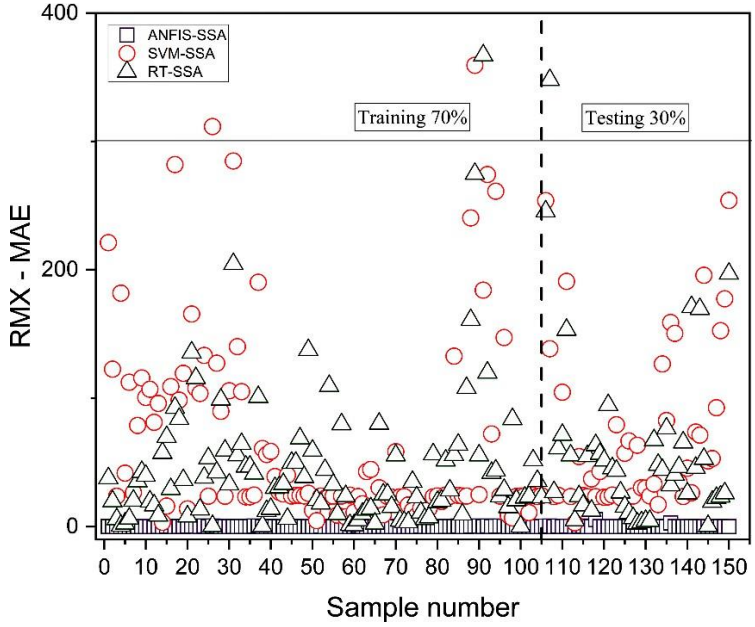

Figure 2: MAE Performance Comparison of RMX Predictions Using SSA-Optimized ML Models

This Figure 2 depicts the MAE of various models, namely SSA of ANFIS, SSA-SVM, and RT, applied to the RMX system over a sequence of sample points. The x-axis represents sample number, spanning from 0 to 150, while the y-axis quantifies MAE values. The data indicates that the SSA-ANFIS model consistently achieves lower MAE values compared to the other models throughout most of the sampling range. This suggests superior prediction accuracy. Notably, an initial decrease in MAE is observed for all models as samples progress, with the SSA-ANFIS model converging towards minimal error earlier than its counterparts. This trend underscores the efficacy of the SSA algorithm in optimizing the ANFIS model parameters, leading to improved performance in modelling the resistance data.

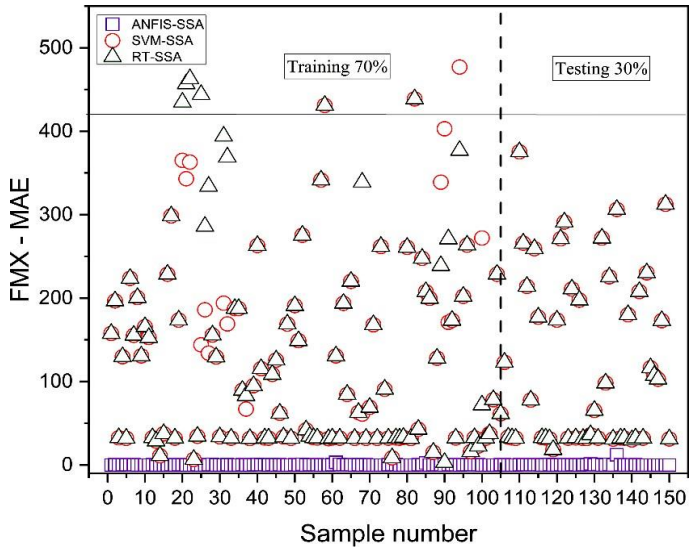

Figure 3: Evaluation of FMX Prediction Error (MAE) for SSA-Tuned Machine Learning Models

This figure 3 illustrates the MAE progression for models integrating SSA with ANFIS, SVM, and RT, applied specifically to the FMX system. The x-axis again depicts sample number, and error magnitude is shown on the y-axis. The graph reveals that the SSA-ANFIS model maintains the lowest MAE across the sample set. There is a rapid decline in error levels after initial samples, with stabilization during the testing phase. In contrast, the SSA-SVM and RT models exhibit higher and more fluctuating MAE values. This indicates less consistent predictive performance. These findings suggest that the SSA-ANFIS hybrid provides a more accurate and stable modelling approach for the force data.

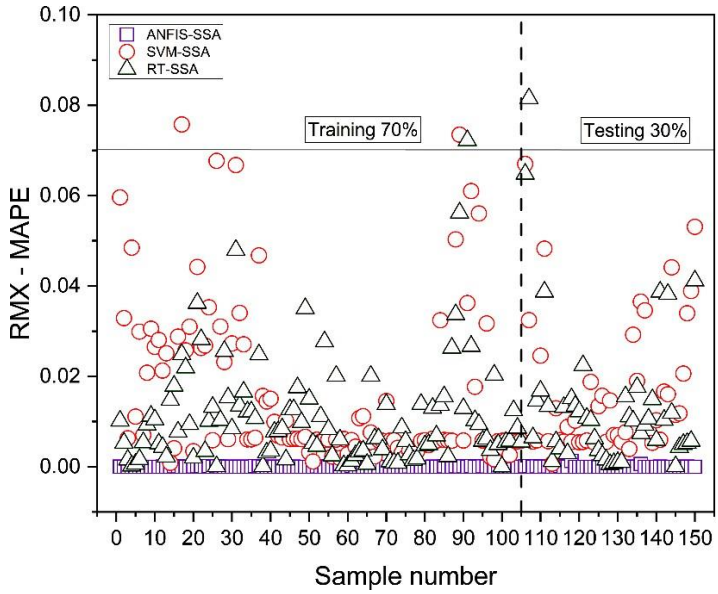

Figure 4: Evaluation of RMX Prediction Error (MAPE) for SSA-Tuned Machine Learning Models

Figure 4 presents the MAPE for the same set of models applied to the RMX system. The x axis covers sample points from 0 to 150, with error percentages plotted on the y-axis. The results demonstrate that the SSA of ANFIS model attains the lowest MAPE values throughout the sampling process. This indicates high prediction accuracy relative to actual resistance measures. The MAPE curves exhibit a sharp decrease early in the sample set, with minor fluctuations during the testing phase. This reflects the model's robustness. Conversely, models based on SVM and RT tend to have higher and less consistent trajectories, pointing to their comparatively lower precision.

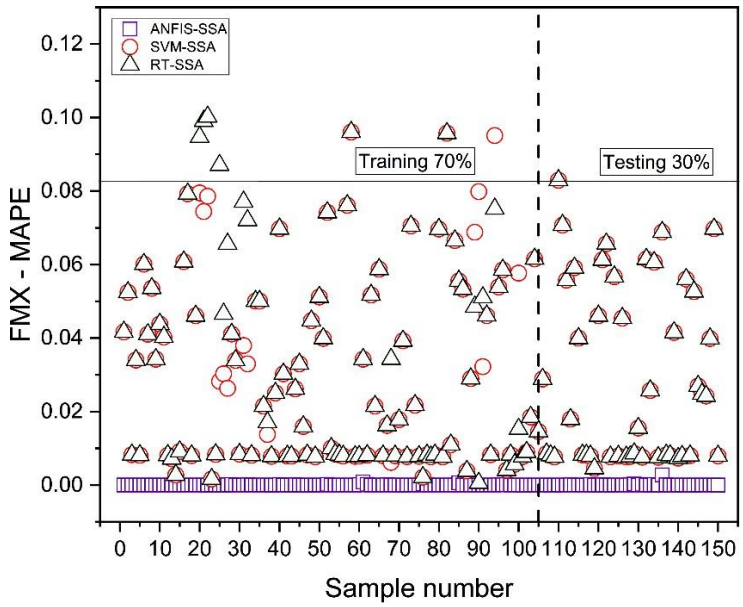

Figure 5: Evaluation of FMX Prediction Error (MAPE) for SSA-Tuned Machine Learning Models

Figure 5 displays the MAPE for models utilizing SSA-optimized of ANFIS, SVM, and RT in modelling the FMX system. As with previous figures, the sample number increases along the x-axis, while the error percentages are shown on the y-axis. The SSA-ANFIS model maintains the lowest MAPE values across the entire sampling spectrum. This highlights its superior accuracy in predicting the maximum force. The curves suggest that optimization through SSA enables the ANFIS model to generalize well on unseen data with minimal errors during the testing phase. Conversely, the SVM and RT models demonstrate higher and more variable MAPE levels. This indicates less reliable predictive performance for force data.

3.4 Application Interface Design and Functionality

To enable practical deployment of the developed predictive models, a graphical user interface (GUI) was designed to support real-time analysis of pile performance. The interface accepts user inputs for critical parameters, including hammer drop height, pile number, penetration depth, ultimate depth from the Mackintosh probe, and set value, each constrained within specified ranges based on the training dataset. Upon input, the system processes these parameters through the optimized machine learning models to generate predictions for RMX and FMX values.

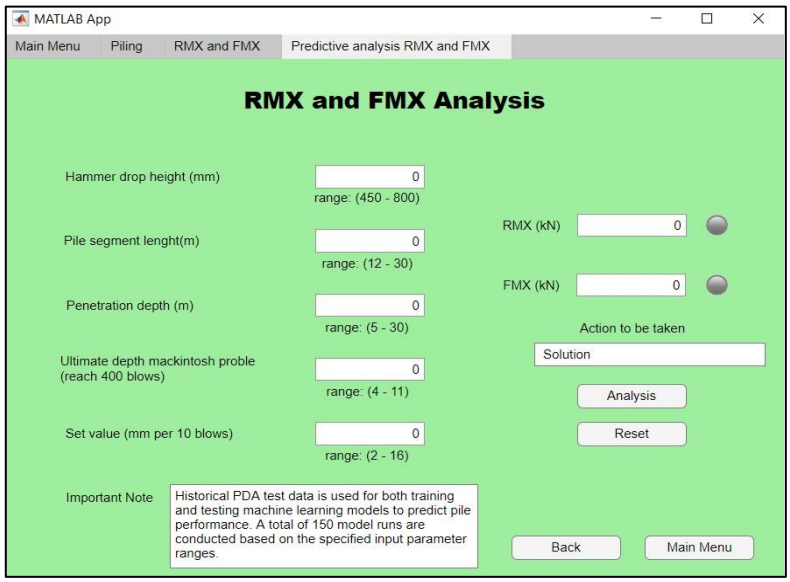

Figure 6: Graphical user interface for RMX and FMX analysis

As shown in Figure 6, the layout is structured to ensure usability in field settings, with clearly labelled inputs, predictive output fields, and supporting functions such as "Analysis," "Reset," and an action recommendation dropdown. An embedded note highlights that the predictive engine was developed using 150 validated PDA records, reinforcing the empirical foundation of the tool. The GUI prototype not only demonstrates the integration of machine learning outputs into a user-accessible platform but also serves as validation of the model's applicability in operational geotechnical environments, offering a time-efficient and cost-effective alternative to conventional pile testing procedures.

3.5 Testing and Validation

To further evaluate the generalization capability of the developed machine learning models, a validation procedure was conducted using data collected from a separate building within the same project site. This dataset, while sourced from the same construction environment, was not used during model training or initial testing phases, ensuring that the validation was conducted on unseen data and thus reflective of real-world predictive performance.

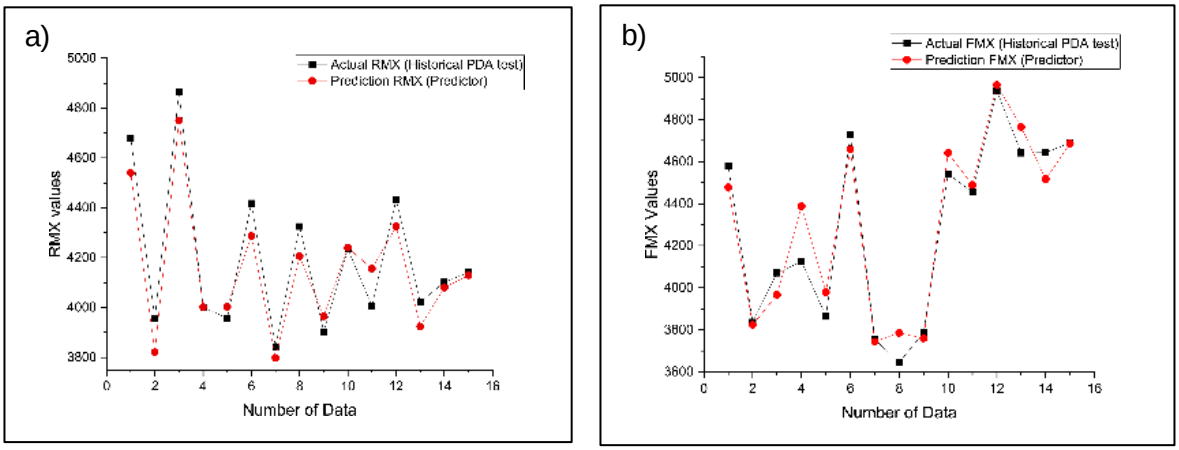

Figure 7: Comparison between predicted and actual values of RMX (a) and FMX (b)

To evaluate the generalization capability of the developed predictive models beyond the original training dataset, a validation exercise was conducted using data obtained from a different building within the same project site. This secondary dataset, which was not involved in the model development, training, or initial testing phases, served as an independent benchmark to assess model performance. The validation process involved comparing the predicted values of RMX and FMX with the actual PDA test results from the secondary structure. As depicted in Figure 7a and Figure 7b, the predicted values closely aligned with the actual measurements across all data points, thereby confirming the optimized model's ability to generalize effectively to new but related conditions and demonstrating its robustness and practical applicability in real-world geotechnical scenarios.

4.0 CONCLUSION

This research successfully developed and validated a hybrid predictive modelling system for spun pile efficiency, integrating machine learning algorithms with metaheuristic optimization techniques. The SSA emerged as the most effective optimizer, significantly improving model accuracy and robustness through efficient hyperparameter tuning. The optimized models exhibited superior predictive performance and computational efficiency, with SSA combined with ANFIS consistently delivering the lowest error metrics across both RMX and FMX outputs. To facilitate practical deployment, these models were integrated into a MATLAB based graphical user interface, offering a user-friendly decision-support tool for engineers in the field. Collectively, the findings underscore the viability of machine learning augmented by metaheuristic optimization as a cost-effective and reliable alternative to conventional pile testing, contributing to enhanced safety and efficiency in geotechnical foundation assessments.

4.1 Recommendations for Future Research

Despite the promising results, certain limitations have been identified, including the scope of the dataset and variability in soil conditions across different sites. These factors may influence model performance in completely unseen environments. Nevertheless, the present study has established a reliable system that can be further refined through expanded data collection and continuous validation, ensuring its adaptability and robustness in diverse geotechnical contexts. First, the refinement of model performance could benefit from the application of advanced optimization techniques, such as Bayesian optimization and multi-objective evolutionary algorithms, which may offer more efficient and accurate hyperparameter tuning. Furthermore, the adoption of ensemble learning approaches or hybrid modelling frameworks may enhance both the predictive accuracy and the robustness of the models across varying geotechnical scenarios. Second, expanding the dataset to include a broader range of pile types, installation conditions, and soil profiles is essential to improve model generalizability. This can be achieved through collaborative data sharing initiatives and integration of multi-source datasets, ultimately enabling the development of more comprehensive and adaptable models. Third, the current modelling approach could be extended to other foundation systems, such as driven piles and drilled shafts, and applied across diverse geotechnical contexts. Investigating model behaviour under different loading conditions and in complex soil environments would provide deeper insights into their applicability and limitations. Finally, industry-scale validation through pilot projects and case studies is vital to demonstrate the practical reliability of these models. Establishing standardized procedures for model implementation, updating, and maintenance would further support their widespread adoption as intelligent decision support tools within the construction and geotechnical engineering sectors.

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APPENDIX

A: Training Results for Adaptive Neuro-Fuzzy Inference System (ANFIS)

	MF Type	RMSE	Number of MFs	RMSE
RMX	trimf	5.25	33333	5.25
			55555	0.21
	trapmf	161.08	33333	161.08
			55555	56.19
	gbellmf	29.47	33333	29.47
			55555	11.13
	gaussmf	34.91	33333	34.91
			55555	20.93
	gauss2mf	65.02	33333	65.09
			55555	24.74
	pimf	166.99	33333	166.99
			55555	58.44
	dsigmf	117.82	33333	117.82
			55555	5.32
	psigmf	117.82	33333	117.82
			55555	5.32
FMX	trimf	18.58	33333	18.58
			55555	0.85
	trapmf	445.68	33333	445.68
			55555	126.68
	gbellmf	129.67	33333	129.67
			55555	78.32
	gaussmf	103.09	33333	103.09
			55555	2.43
	gauss2mf	92.17	33333	92.17
			55555	27.19
	pimf	440.40	33333	440.40
			55555	144.15
	dsigmf	430.25	33333	430.25
			55555	20.21
	psigmf	430.25	33333	430.25
			55555	20.21

Appendix B: Training Results for Support Vector Machine (SVM) Configurations

	Hyperparameter Tuning	RMSE Value	R^2 Value
RMX	Linear SVM	176.94	0.51
	Linear RT (PCA)	176.07	0.52
	Quadratic SVM	181.80	0.48
	Quadratic SVM (PCA)	175.59	0.52
	Qubic SVM	176.53	0.51
	Qubic SVM (PCA)	176.57	0.51
	Fine Gaussion SVM	178.11	0.50
	Fine Gaussion SVM (PCA)	171.30	0.54
	Medium Gaussion SVM	178.51	0.50
	Medium Gaussion SVM (PCA)	178.58	0.52
	Coarse Gaussion SVM	180.58	0.49
	Coarse Gaussion SVM (PCA)	178.38	0.50
	Optimizable SVM (Bayesian)	179.42	0.50
	Optimizable SVM (Grid search)	240.07	0.10
	Optimizable SVM (Random search)	175.00	0.52
	Optimizable SVM (Bayesian)	154.31	0.63
	Optimizable SVM (Grid search)	175.48	0.52
	Optimizable SVM (Random search)	177.98	0.50
FMX	Linear SVM	176.85	0.51
	Linear SVM (PCA)	176.12	0.52
	Quadratic SVM	181.27	0.49
	Quadratic SVM (PCA)	175.78	0.52
	Qubic SVM	177.96	0.51
	Qubic SVM (PCA)	177.09	0.51
	Fine Gaussion SVM	178.91	0.50
	Fine Gaussion SVM (PCA)	171.39	0.54
	Medium Gaussion SVM	178.30	0.50
	Medium Gaussion SVM (PCA)	175.69	0.52
	Coarse Gaussion SVM	180.66	0.49
	Coarse Gaussion SVM (PCA)	178.55	0.50
	Optimizable SVM (Bayesian)	200.71	0.37
	Optimizable SVM (Grid search)	176.37	0.51
	Optimizable SVM (Random search)	172.66	0.54
	Optimizable SVM (Bayesian)	177.67	0.51
	Optimizable SVM (Grid search)	251.80	0.01
	Optimizable SVM (Random search)	179.30	0.50

Appendix C: Training Results for Regression Tree (RT) Configurations

	Hyperparameter Tuning	RMSE Value	R^2 Value
RMX	Fine Tree	182.99	0.48
	Fine Tree (Hyperparameter)	182.99	0.48
	Fine Tree (Hyperparameter)	182.99	0.48
	Fine Tree (PCA)	155.18	0.62
	Medium Tree	162.18	0.59
	Medium Tree (Hyperparameter)	162.76	0.59
	Medium Tree (Hyperparameter)	162.76	0.59
	Medium Tree (PCA)	162.76	0.57
	Coarse Tree	165.35	0.52
	Coarse Tree (Hyperparameter)	175.70	0.52
	Coarse Tree (Hyperparameter)	175.70	0.52
	Coarse Tree (PCA)	175.62	0.52
	Optimizable Tree (Bayesian)	155.18	0.62
	Optimizable Tree (Grid Search)	155.18	0.62
	Optimizable Tree (Random Search)	155.18	0.62
	Optimizable Tree (Bayesian)	163.33	0.58
	Optimizable Tree (Grid Search)	163.33	0.58
	Optimizable Tree (Random Search)	163.33	0.58
FMX	Fine Tree	720.78	-0.41
	Fine Tree (Hyperparameter)	720.78	-0.41
	Fine Tree (Hyperparameter)	720.78	-0.41
	Fine Tree (PCA)	682.63	-0.26
	Medium Tree	614.66	-0.02
	Medium Tree (Hyperparameter)	614.66	-0.02
	Medium Tree (Hyperparameter)	614.66	-0.02
	Medium Tree (PCA)	645.67	-0.13
	Coarse Tree	628.50	-0.07
	Coarse Tree (Hyperparameter)	628.50	-0.07
	Coarse Tree (Hyperparameter)	628.50	-0.07
	Coarse Tree (PCA)	630.21	-0.08
	Optimizable Tree (Bayesian)	607.47	0.00
	Optimizable Tree (Grid Search)	607.47	0.00
	Optimizable Tree (Random Search)	614.39	-0.02
	Optimizable Tree (Bayesian)	579.88	0.09
	Optimizable Tree (Grid Search)	574.09	0.11
	Optimizable Tree (Random Search)	613.05	-0.02

Enhancing Defect Management Through Web-Based Platform for Rectification Work Progress Record and Defect Control

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ABSTRACT

The Defect Liability Period (DLP) is a crucial phase in construction quality assurance, yet current defect management practices remain heavily dependent on manual methods such as printed memos and informal communication. These traditional workflows often lead to delayed responses, scattered documentation, and limited accountability, especially in handling Defect Site Instructions (DSIs). This study introduces "Memo Manager," a web-based platform developed to digitize and streamline the issuance, acknowledgment, and tracking of DSIs between main contractors and subcontractors. The research adopted a Design and Development Research (DDR) methodology and was guided by three objectives: (1) to identify problems in the current workflow of defect management practices in a construction project, (2) to develop a comprehensive web-based defect management system that enhances the communication and documentation of DSIs, and (3) to evaluate the system's usability, functionality, and user satisfaction based on feedback from actual construction project users. System development followed a structured approach using HTML, JavaScript, and Firebase for real-time task management and digital signature uploads. Data was collected through field observations, usability testing, and structured questionnaires. A total of 81 respondents, comprising 47 subcontractors and 34 main contractors participated in the final evaluation. The System Usability Scale (SUS) was used as the core instrument to assess system usability, supported by Likert-scale feedback for detailed evaluation. Findings revealed improved communication, faster acknowledgment, and higher satisfaction levels. The results validate that Memo Manager offers a scalable, practical solution for enhancing defect management during DLP while supporting Malaysia's Construction 4.0 goals.

Keywords: Defect Liability Period (DLP); Defect Site Instruction (DSI); Web-based system; Construction 4.0; Usability evaluation; System Usability Scale (SUS); Construction management; Digital defect tracking; Design and Development Research (DDR)

1.0 INTRODUCTION

Defect management is a vital component of construction quality control, particularly during the Defect Liability Period (DLP), which ensures that construction defects are systematically identified and rectified after project completion. In Malaysia, the DLP is still predominantly managed through conventional and fragmented methods such as emails, printed memos, and informal messaging platforms like WhatsApp (Hamdan, 2022; Nouh et al., 2023). These manual processes are inefficient and prone to delays, leading to uncoordinated updates, incomplete documentation, and reduced accountability concerns widely documented in both local and international studies (Khamidi et al., 2022; Rahimin et al., 2024).

Furthermore, the lack of centralized tracking for Defect Site Instructions (DSIs) results in disorganized records and ineffective monitoring. Studies by Kariya et al. (2016) and Naqeeb (2023) confirm that inconsistencies in record-keeping hinder auditing efforts and increase the risk of disputes and legal exposure. AiBinu and Paton-Cole (2023) as well as Lambers (2019) also highlighted how verbal updates and unstructured inspections compromise traceability and project oversight.

To address these shortcomings, this study introduces a practical digital intervention the Memo Manager a web-based platform designed to digitize and streamline the issuance, acknowledgment, and monitoring of DSIs. This aligns with the Construction 4.0 vision by promoting centralized, real-time communication and reducing administrative burdens through automation. The objectives of this research are threefold: (1) to identify inefficiencies in the current defect management workflow, (2) to develop a web-based platform that facilitates seamless DSI communication and documentation, and (3) to evaluate the system's usability, functionality, and user satisfaction based on data collected from real construction project environments.

By implementing a centralized digital platform, this study contributes a scalable and efficient solution to a longstanding issue in construction management. The Memo Manager system improves traceability, ensures faster response times, and enhances collaboration between main contractors and subcontractors ultimately raising the standard of defect resolution and increasing client satisfaction (Nouh et al., 2023; Aibinu & Paton-Cole, 2023).

2.0 METHODOLOGY

The development of the Memo Manager system followed the Design and Development Research (DDR) methodology, structured into three key phases: Planning, Development, and Evaluation. This approach ensured that the system was both problem-driven and user-validated through iterative improvements.

In Phase 1: Planning, the study began with identifying critical issues in the current defect management workflow, such as delayed ACKNOWLEDGMENT, lack of centralized tracking, and scattered documentation through direct observations on an active construction project. A requirement analysis was conducted to define system functionalities that directly address these challenges. Research objectives were aligned with previous findings, such as those by Khamidi et al. (2022) and Nouh et al. (2023), who highlighted the inefficiencies in manual DSI handling. This phase also included the design of a user feedback survey to validate pain points and system requirements with real stakeholders.

In Phase 2: System Development, system requirements were translated into a functional prototype. The platform was built with two dedicated user interfaces: one for main contractors and one for subcontractors, tailored to their distinct roles in the DSI workflow. The front-end was developed using HTML, CSS, and JavaScript, while Firebase was used as the back-end for authentication, data management, and memo file storage. Key features included digital DSI issuance, signature uploads, dashboard views, and real-time filtering of DSI statuses. After internal testing (unit and integration), a prototype testing session was conducted in a live project setting. Based on observed usability issues and user input during this session, a refinement stage was introduced. This step focused on improving layout responsiveness, button labelling, and error handling to enhance user interaction before final evaluation.

In Phase 3: Implementation and Evaluation, the refined system was deployed in the actual site environment. A demonstration was provided to subcontractors and site supervisors, followed by a structured usability assessment. The System Usability Scale (SUS) and a detailed user survey were used to measure ease of use, perceived functionality, and satisfaction. A total of 81 respondents participated in the survey, comprising 47 subcontractors and 34 main contractors. The study deployed a survey design via questionnaire for data collection. There were two types of questionnaires; one for Subcontractors and the other one is for Main contractor. Both instruments were divided into three section; Section A, B, and C.

Section A is to assess the perceived limitations of traditional defect communication methods from both subcontractor and main contractor perspectives. Section B intend to assess how the Memo Manager system improves defect communication processes for both subcontractors and main contractors compared to traditional methods. While section C consists the overall user experience and satisfaction levels of subcontractors and main contractors after using the Memo Manager platform. This evaluation approach provided comprehensive feedback to determine the system's practical value and user acceptance within the construction project environment.

3.0 RESULTS AND DISCUSSION

This section presents the findings of the study, structured around three key research objectives: (1) identifying issues in the current defect management workflow, (2) developing the Memo Manager system, and (3) evaluating its usability and effectiveness based on user feedback.

3.1 Identifying Workflow Issues in Defect Management

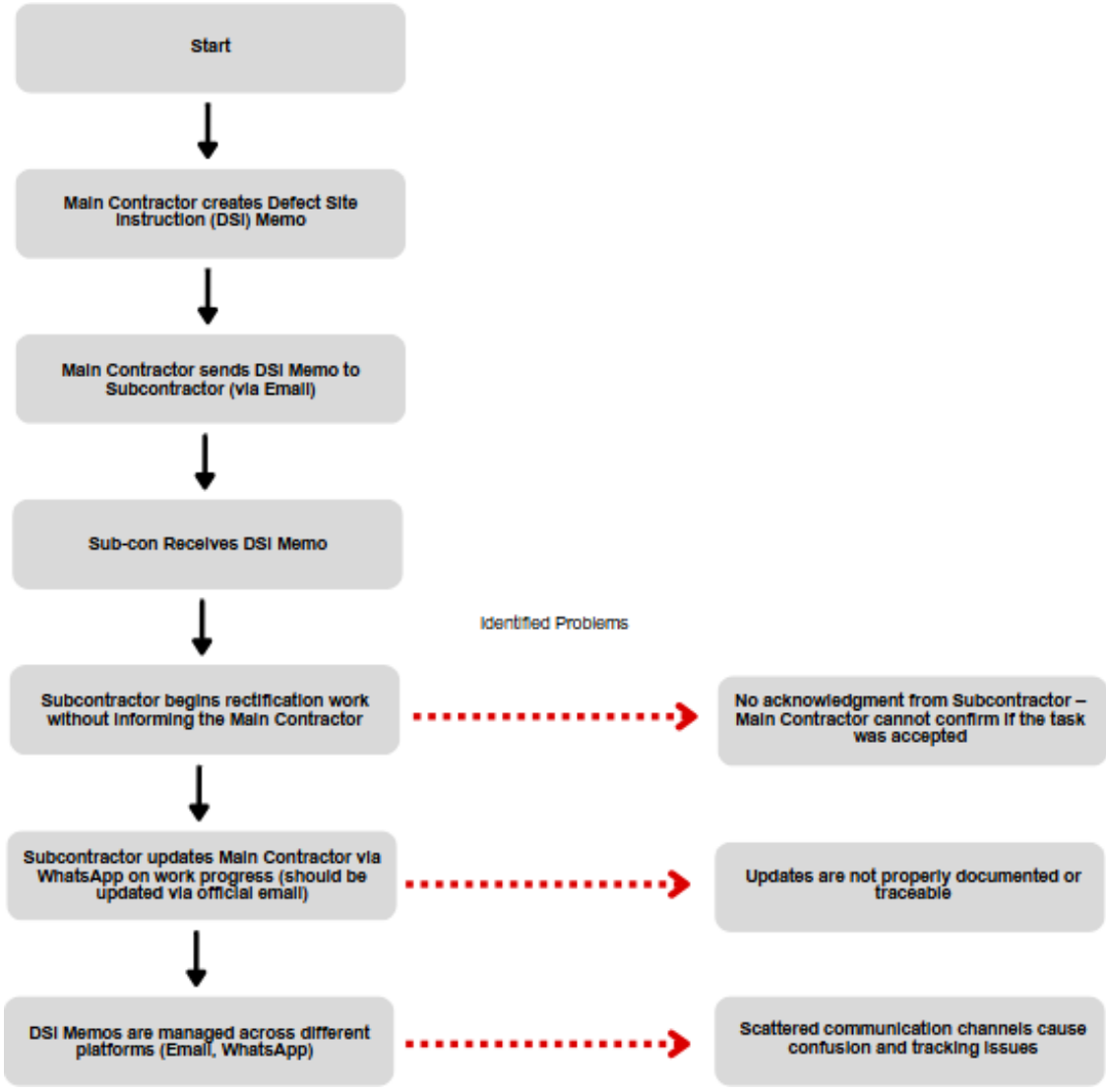

Figure 1: Current Defect Management Workflow and Associated Problems

As shown in Figure 1, the traditional workflow for managing Defect Site Instructions (DSIs) in construction projects is primarily manual and relies on fragmented communication. The process begins with the main contractor preparing and issuing a Defect Site Instruction (DSI) memo. This memo is typically sent to the subcontractor via email. Upon receiving the DSI, the subcontractor is expected to carry out rectification work. However, several critical issues arise throughout this workflow, undermining its efficiency and reliability.

First, there is no formal acknowledgment mechanism for the subcontractor to confirm receipt and acceptance of the DSI. This lack of confirmation prevents the main contractor from verifying whether the instruction has been seen and understood, introducing delays and uncertainties in task execution. Secondly, once rectification begins, the subcontractor typically provides progress updates via informal channels such as WhatsApp. These updates are not systematically recorded or stored, leading to poor documentation and limited traceability.

Additionally, communication across different platforms including email, WhatsApp, and sometimes printed documents results in scattered information. This fragmentation complicates tracking and follow-up actions, particularly when multiple DSIs are issued or pending. Consequently, the main contractor faces difficulties in maintaining a reliable audit trail of defect-related activities, which can negatively impact project timelines, accountability, and overall quality assurance.

These identified problems highlight the urgent need for a centralized, structured system that supports task acknowledgment, formalized updates, and unified documentation. Addressing these gaps is essential for improving communication, ensuring accountability, and streamlining defect rectification processes within construction projects.

3.2 Development of the Memo Manager System

To address the limitations identified in traditional defect workflows, the Memo Manager system was developed with distinct interfaces tailored to the needs of subcontractors and main contractors. Each interface was designed to simplify communication, ensure traceability, and enhance user experience. As depicted in Figure 2, the system includes a Login Interface, which provides secure access through email and password authentication.

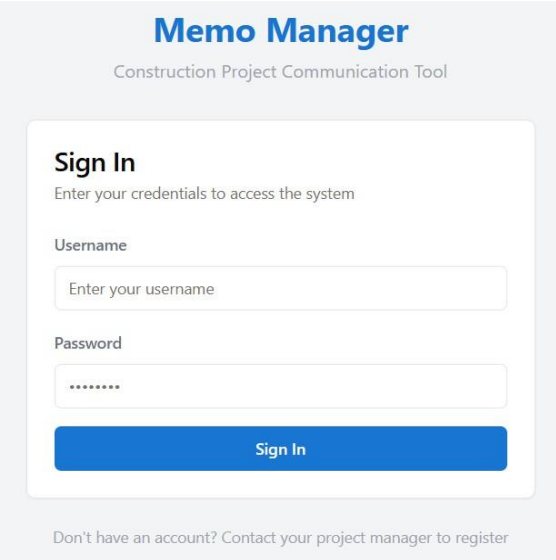

Figure 2: Login Interface

As shown in Figure 3, the Dashboard Interface provides a centralized view of received DSIs, their status, and recent updates, improving visibility and response time.

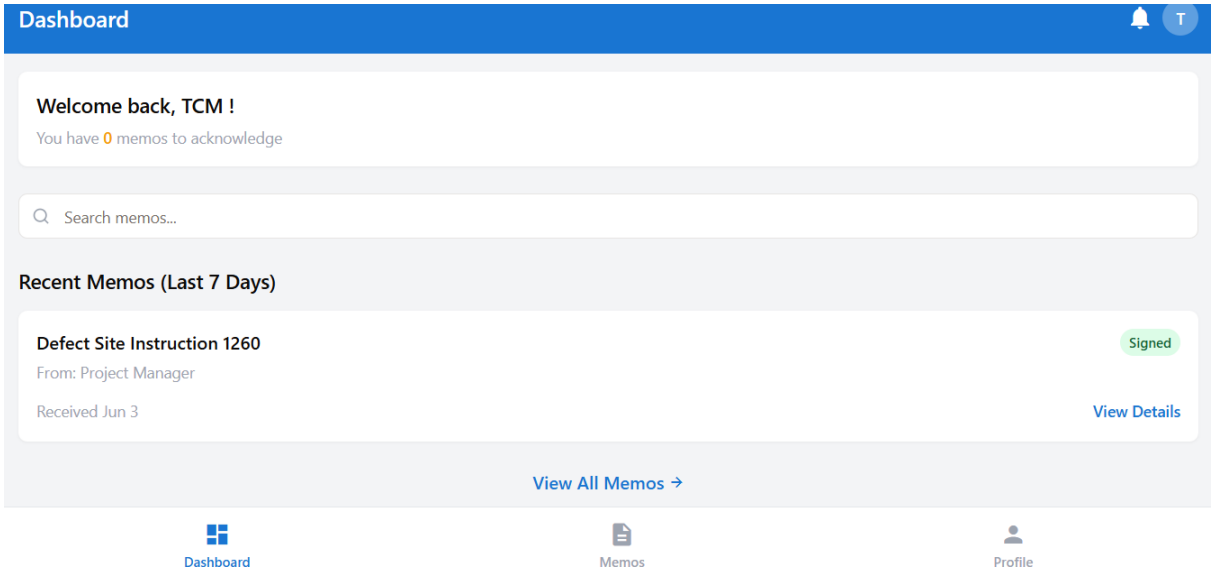

Figure 3: Dashboard Interface

While the Digital Acknowledgment and Signature feature as depicted in Figure 4 allows subcontractors to confirm receipt with a timestamped signature, eliminating the need for printing and scanning. These features streamline defect communication by replacing scattered emails with real-time, trackable interactions. The system improves task clarity, speeds up acknowledgment, and ensures documentation is securely archived, all contributing to better coordination, traceability, and accountability in construction workflows.

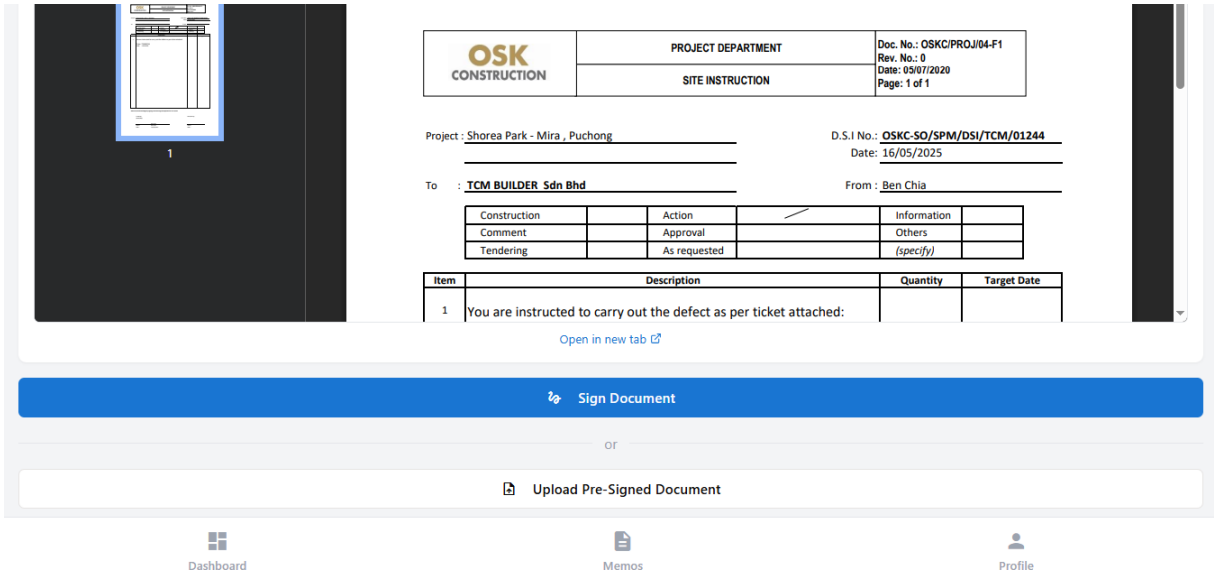

Figure 4: Digital Acknowledgment and Signature

For main contractors, the Memo Manager system provides a centralized and secure platform to manage Defect Site Instructions (DSIs). As shown in Figure 5, the Dashboard Overview gives a clear snapshot of all DSIs, including pending and acknowledged statuses, streamlining memo monitoring and issuance without relying on scattered emails or manual follow-ups.

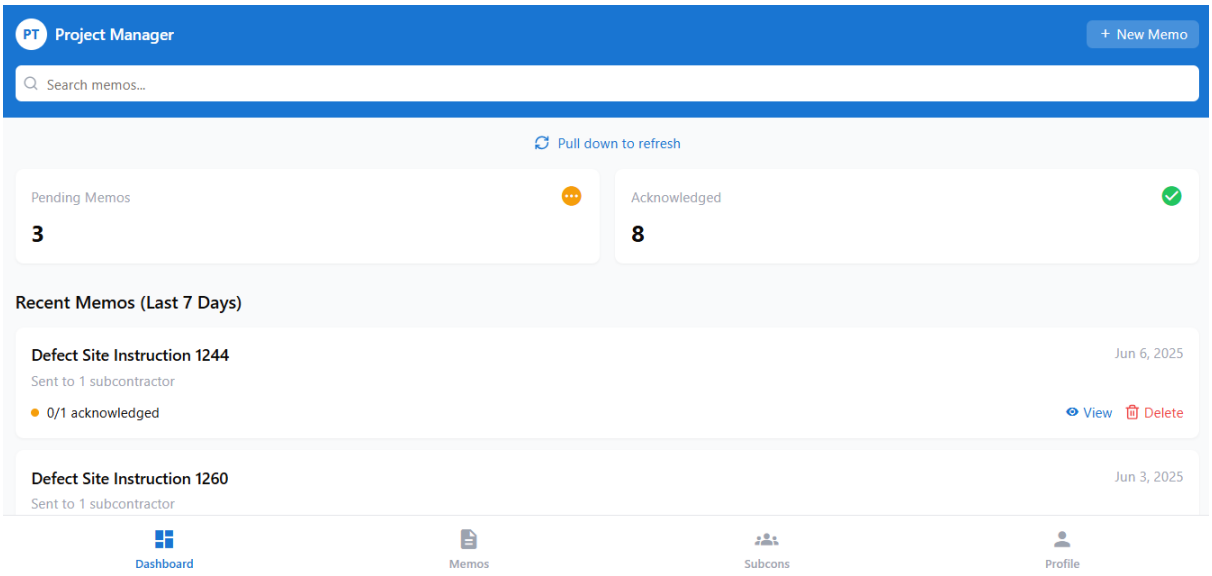

Figure 5: Main Contractor Dashboard Overview

The Memo Tracking Panel enhances real-time oversight by showing acknowledgment progress and filtering memos by status, helping project teams stay updated on outstanding defects. Additionally, the Subcontractor Management Interface provides a structured directory for managing subcontractor contacts and streamlines task assignment through a searchable, organized list, as depicted in Figure 6.

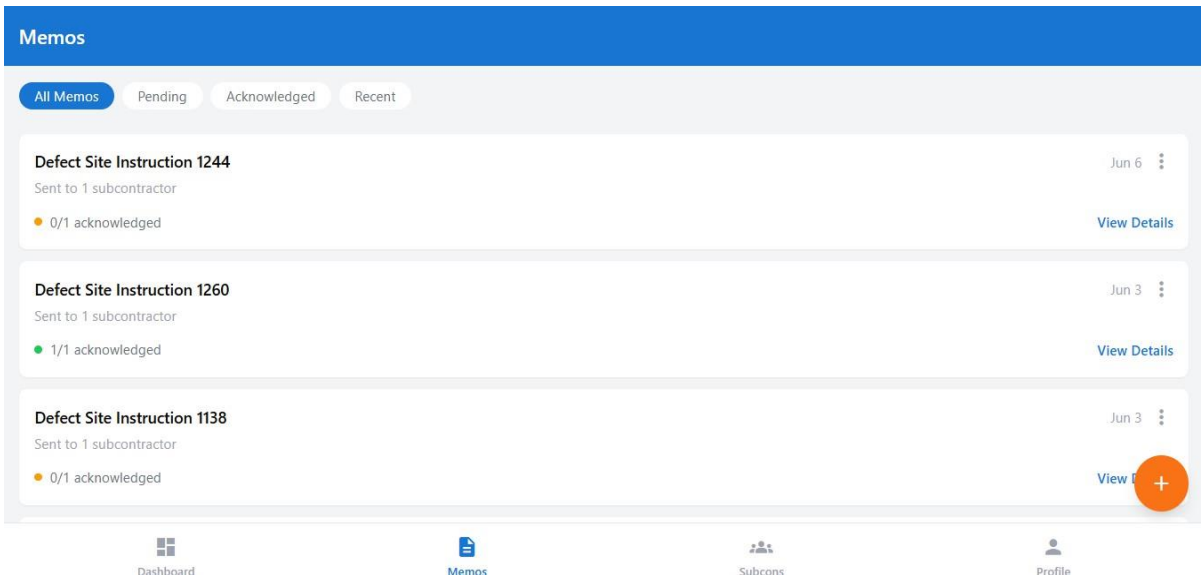

Figure 6: Memo Tracking Panel

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Together, these interfaces resolve key inefficiencies in traditional workflows by improving visibility, traceability, and accountability, ultimately supporting faster and more reliable defect resolution across projects.

3.3 System Evaluation (Usability and Satisfaction)

3.3.1 Subcontractor User Feedback Result

As shown in Table 1, The results indicate that subcontractors generally found the traditional method of defect communication inefficient and cumbersome. The highest mean score of 3.87 was given to the statement regarding the lack of a centralized system for tracking acknowledged DSIs, highlighting a significant gap in documentation and tracking. Other aspects such as the perception of email-based communication being time-consuming and the difficulty in updating the main contractor after rectification received slightly lower but still notable mean scores around 3.72–3.74. With an overall average mean of 3.76 and a standard deviation of 1.02, the feedback suggests moderate dissatisfaction with traditional practices, underlining the need for a more streamlined and structured system.

Table 1: Traditional Defect Communication

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	Perception on Receiving Defect Memos via Email Being Time-Consuming	0	17.0	25.5	23.4	34.0	3.74	1.11
2	Perception on Delays Caused by Downloading, Printing, and Signing DSIs	0	12.8	27.7	34.0	25.5	3.72	0.99
3	Perception on the Difficulty of Updating the Main Contractor After Rectification	0	14.9	23.4	36.2	25.5	3.72	1.02
4	Perception on the Lack of a Centralized System for Tracking Acknowledged DSIs	0	12.8	19.1	36.2	31.9	3.87	1.01
Average							3.76	1.02

In contrast to the traditional system, as depicted in Table 2 subcontractors expressed a higher level of satisfaction with the web-based platform. The highest rating was for the simplicity of uploading signed memos through the platform, which scored a mean of 3.89, indicating that digital submission was perceived as a major improvement over manual processes. Perceptions on checking pending or completed DSIs (mean = 3.83) and improving communication with the main contractor (mean = 3.83) also showed favourable responses. However, receiving DSIs through the platform received a slightly lower score of 3.60, possibly due to the learning curve associated with new technology. With an average mean of 3.78 and standard deviation of 1.03, the platform was overall well-received, showing that digital tools can significantly enhance defect communication workflows.

Table 2: Web-Based Platform Usage

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	Perception on Receiving DSIs Through the Platform Being Easier Than Email	0	14.9	31.9	31.9	21.3	3.6	0.99
2	Perception on the Simplicity of Uploading Signed Memos Through the Platform	0	10.6	29.8	19.1	40.4	3.89	1.06
3	Perception on the Ease of Checking Pending or Completed DSIs	0	19.1	14.9	29.8	36.2	3.83	1.13
4	Perception on Receiving Helpful Reminders and Notifications	0	14.9	21.3	36.2	27.7	3.77	1.03

As presented in Table 3, User experience with the platform was largely positive, although slightly less enthusiastic compared to the communication aspect. Subcontractors rated the system's time efficiency over manual processes the highest, with a mean of 3.85, reflecting their appreciation for how the platform reduced turnaround time. However, the process of submitting updates and documents received the lowest rating of 3.57, suggesting some technical or usability challenges may still exist in that feature. The average mean score was 3.71, with a standard deviation of 1.11, indicating varied experiences among users. These findings suggest that while the platform is generally seen as user friendly, further improvements to the interface and submission process could enhance the overall user experience.

Table 3: User Experience

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	Perception on the Platform Interface Being User-Friendly and Easy to Navigate	0	21.3	17.0	34.0	27.7	3.68	1.11
2	Perception on Submitting Updates and Documents as a Smooth Process	0	23.4	21.3	29.8	25.5	3.57	1.12
3	Perception on Time Efficiency of the System Compared to Manual Processes	0	14.9	17.0	36.2	31.9	3.85	1.04

4	Perception on Increased Accountability When Using the Platform	0	23.4	10.6	34.0	31.9	3.74	1.15
Average							3.71	1.11

3.3.2 Main Contractor User Feedback Result

While feedback from main contractor as noted in Table 4, Main contractors, much like subcontractors, highlighted multiple issues with the traditional approach to defect oversight. The highest concern was the difficulty of maintaining defect records across units, which received a mean score of 3.82, emphasizing poor recordkeeping and traceability. Manual monitoring of rectification progress (mean = 3.76) and delays in DSI handling (mean = 3.79) were also flagged as persistent problems. The lowest-rated aspect was the timeliness of subcontractor DSI acknowledgment, which scored 3.56. This table's average mean score was 3.73 with a standard deviation of 1.01, illustrating that traditional systems were seen as a barrier to effective defect oversight, especially in terms of documentation and timely updates.

Table 4: Defect Oversight in Traditional Systems

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	Perception of Manual DSI Handling Delays	0	8.8	26.5	41.2	8	3.79	0.91
2	Perception on Timeliness of Subcontractor DSI Acknowledgement	0	23.5	26.5	20.6	29.4	3.56	1.16
3	Perception on Manual Monitoring of Rectification Progress	0	8.8	29.4	38.2	23.5	3.76	0.92
4	Perception on Difficulty Maintaining Defect Records Across Units	0	14.7	20.6	32.4	32.4	3.82	1.06
Average							3.73	1.01

As indicated in Table 5, this table demonstrated a clear improvement in main contractor satisfaction when using the Memo Manager platform. The highest rating was given to the ease of accessing defect histories, which scored a strong mean of 4.12, signifying high approval for this digital feature. The ability to monitor rectification progress in real time and faster acknowledgment via the platform also received favourable scores, with means of 3.88 and 3.79 respectively. Although slightly lower, identifying unresolved work via the platform still earned a respectable mean of 3.71. The average across this table was 3.83 with a standard deviation of 0.97, confirming that the platform provided a more efficient and transparent method for managing and monitoring defects than the manual system.

Table 5: Monitoring & Oversight via the Platform

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	User Perception on Improved Communication via Web-Based System	0	17.6	23.5	26.5	32.4	3.74	1.11
2	User Perception on Faster Acknowledgement via Platform	0	8.8	32.4	29.4	29.4	3.79	0.98
3	User Perception on Real-Time Monitoring of Rectification Progress	0	5.9	23.5	47.1	23.5	3.88	0.84
4	User Perception on Ease of Access to Defect Histories	0	5.9	17.6	35.3	41.2	4.12	0.91
5	Perception on Identifying Unresolved or Delayed Work via Platform	0	11.8	35.3	23.5	29.4	3.71	1.03
6	User Perception on System Control of Rectification Workflows	0	14.7	20.6	41.2	23.5	3.74	0.99
Average							3.83	0.97

Among all results, Table 6 for main contractors revealed the highest levels of satisfaction. The time efficiency of the platform compared to manual oversight received a top score of 4.06, underscoring how the system saved time and improved workflow speed. Document upload and tracking simplicity also scored highly at 4.03. Although the perception of improved accountability was somewhat lower at 3.68, it still indicated moderate approval. With an overall average mean of 3.89 and standard deviation of 0.99, these results reflect the platform's success in meeting the main contractors' expectations, particularly in areas related to management control, usability, and time-saving.

Table 6: Management Satisfaction

No	Item	Percentage (%)					Mean	Standard Deviation
		1	2	3	4	5		
1	User Perception on Platform Interface Usability for Site Staff	0	20.6	8.8	41.2	29.4	3.79	1.09

2	User Perception on Document Upload and Tracking Simplicity	0	5.9	17.6	44.1	32.4	4.03	0.87
3	User Perception on Time Efficiency Compared to Manual Oversight	0	5.9	20.6	35.3	38.2	4.06	0.92
4	User Perception on Improved Accountability Across Teams	0	17.6	23.5	32.4	26.5	3.68	1.07
Average							2.99	0.99

Overall, the results confirm that the Memo Manager system effectively addresses key pain points in traditional workflows. The digital platform not only enhances operational efficiency but also improves transparency, task accountability, and user satisfaction. These findings validate the system's relevance and potential for broader implementation in defect management practices within the Malaysian construction industry.

4.0 CONCLUSION

This study set out to address key inefficiencies in defect communication and management within construction projects by developing a web-based platform called Memo Manager. Through a structured research approach, three main objectives were achieved: identifying problems in the current defect management workflow, developing a digital system to improve communication and traceability, and evaluating the system's usability and effectiveness through industry feedback.

The findings revealed that traditional methods such as email-based communication and manual tracking lead to delayed acknowledgment, fragmented documentation, and lack of accountability. The developed Memo Manager system successfully addressed these issues by introducing a centralized platform that facilitates digital issuance, acknowledgment, and monitoring of Defect Site Instructions (DSIs). User evaluations from both subcontractors and main contractors confirmed that the system enhanced usability, improved task visibility, and promoted faster rectification processes.

The practical implications of this study are significant. The Memo Manager platform not only streamlines defect workflows but also fosters better collaboration between stakeholders and strengthens quality control during the Defect Liability Period. Its scalability and intuitive design allow for future integration with other construction management tools.

For future research, the system could be expanded into a mobile application and integrated with real-time notification systems or project scheduling tools. Additional modules such as inspection reporting or automated performance tracking could further enhance its impact and applicability across broader construction environments.

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Integration Of Solar Energy Solution In LEED Certified Building As A Sustainable Energy Strategy

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ABSTRACT

The integration of renewable energy in high energy buildings is important for the long-term sustainability in construction industry. The rising of energy consumption in data centre building highlight the urgent need to integrate the solar energy as sustainable solution. Leadership in Energy and Environmental Design (LEED) certification encourage the integration of clean energy to promote sustainability especially in construction industry. Therefore, the objectives of the study are to investigate the role of solar energy in LEED certification, identify the energy needs at the study area and to evaluate the challenges of solar energy implementation. First and foremost, the energy data were gathered by analyzing the input from the cooling system equipment focusing on Fan Wall (FW), Coolant Distribution Unit (CDU), Electric Vehicle Charge Point (EVCP) and Computer Room Air Handler (CRAH) and comparing it with the energy output of the proposed solar panels. Additionally, the surveys were carried out to assess the challenges in solar energy implementation. As the result, the related cooling system equipment contributes 47.26% of the total energy demand of the data centre building. To meet this demand, estimated 23500 nos of panels and approximately 15.07 acre of land would be required for a dedicated solar farm. The feedback from the respondents highlights the key concern as high initial costs, complexity, implementation impacts and solar energy potential. In conclusion, the solar energy is a sustainable solution for high-energy demand building which contribute to LEED certification with consideration of space availability and cost efficiency.

Keywords: LEED, data centre, cooling system, solar panel

1.0 INTRODUCTION

Renewable energy refers to the energy that comes from the natural sources which replenished faster than they are consumed (Davenport, et al., 2024). The renewable energy is highly recommended to be used as a strategy to mitigate climate change, reducing the air pollution and lowering greenhouse gas emissions at the same time having low operational cost compared to the traditional method. In fact, renewable energy sources seem to provide approximately 29% of global electricity generation in 2020 and will continue to rise (Soergel, et al., 2021). The potential environmental and economic benefits make the renewable energy as a cornerstone to achieve a sustainable and resilient energy future.

Solar energy is currently one of the most utilized renewable energies nowadays. It is harnessing the sunlight to generate electricity and heat which make it the most abundant and sustainable energy sources available. It involves the solar photovoltaic (PV) systems which convert the sunlight directly into electricity (Maka & Alabid, 2022). Solar energy plays a crucial role in reducing the greenhouse gas emissions and provide the clean alternative to fossil fuels. In 2020, solar energy has contributed approximately 3% of the global electricity (Soergel, et al., 2021). The integration of solar energy into the grid enhances the energy security by diverting the energy supply and decreasing dependency on imported fuels which will be the key to the transition towards low-carbon and sustainable future.

Leadership in Energy and Environmental Design (LEED) is the recognized certification system for green buildings. It was the idea from U.S. Green Building Council (USGBC) to promote the

sustainability in building design, construction, operation and maintenance (Council, 2024). It offers the framework for healthy, efficient and cost-saving green buildings. The green building that is certified under LEED may contribute to reducing energy consumption and lowering carbon emissions. The LEED provides the framework for implementation of cost-saving measures in the building projects (Walsh, 2024). If the building has the green building certification, it has the reputation for environmental responsibility. Overall, LEED standards have an important role in addressing global environmental challenges.

Data centre is the centralized facility which store, manage and disseminate of data and information by an organization. Annually, data centre building would consume approximately 20GW and is predicted to increasing to 35GW by 2030 (Gooding, 2024). The high consumption of energy may contribute to the global energy demand and raises the concern on the environment impact, particularly greenhouse gas emissions and increasing of the carbon footprint (Niewenhuis, Iosup, Talluri, & Matteis, 2024). This challenge shows the urgency of finding the sustainable energy integration to the data centre building. Solar energy is an alternative to supply the clean and renewable power source that can fulfil the large energy demands of data centre building. By adopt the solar energy in data centre building, the environmental impact could reduce but the feasibility and effectiveness of this integration need to be investigated and explore. In short, how much solar energy contribute to generate the effective green energy to the data centre building operations?

With that, the objectives of this study are focusing on evaluating the adaptation of solar energy in term of green building certification. Firstly, this study aims to investigate the role of solar energy in contributing to the requirements in LEED certification. Secondly, it seeks to identify the energy needs at the study area. Additionally, the study evaluated the challenges of the implementation of solar energy. Together, these objectives support the effort on how solar energy can be strategically applied to enhance sustainable building practices.

This study will focus on the two-storey data centre with 480MWh energy demand. The energy input is gathered from the cooling system equipment focusing on Fan Wall (FW), Coolant Distribution Unit (CDU), Electric Vehicle Charge Point (EVCP) and Computer Room Air Handler (CRAH). The Trina Solar Vertex N Bifacial Dual Glass Monocrystalline Module is chosen as the solar panel with 605W maximum power output. There are 50 respondents for the questionnaire from the engineering background.

Integration of solar energy may reduce the carbon footprint of the data centre building which align with the global initiatives to fight for climate change. In Google's 2024 Environmental Report, it was stated that 13% rise in greenhouse gas emission attribute to the increasing of data centre building energy demands (Adams, 2024). The transition into solar energy can significantly mitigate the environmental impact and promoting the greener future as it supports Sustainable Development Goal 7 (SDG7) which advocates for affordable, reliable, sustainable, and modern energy for all (Hens & Ren, 2024). Consequently, this study aims to provide the evidence-based recommendations for implementing the solar energy in data centre, contribute against climate change and adapting sustainability for data centre design and operation.

2.0 METHODOLOGY

2.1 Study Area

This integration of solar energy into a new project especially data centre building is recognized as a significant step towards achieving the sustainability in the industry. This study will focus on the benefits on implementing a hybrid solar photovoltaic system in a two-storey data centre building. The data centre building required uninterruptable service as it is an IT infrastructure. Majority of the energy demand comes from the cooling systems to maintain optimal temperature

and prevent overheating. However, specific details regarding the existing energy system cannot be disclosed due to privacy and confidentiality restriction. Figure 1 shows the study area.

Figure 1: Study area

2.2 Research Framework

The current energy consumption of the data centre building and potential energy generated by the solar photovoltaics systems is analyzed to provide a decision on the necessity of implementing solar energy. The research framework is shown in Figure 2.

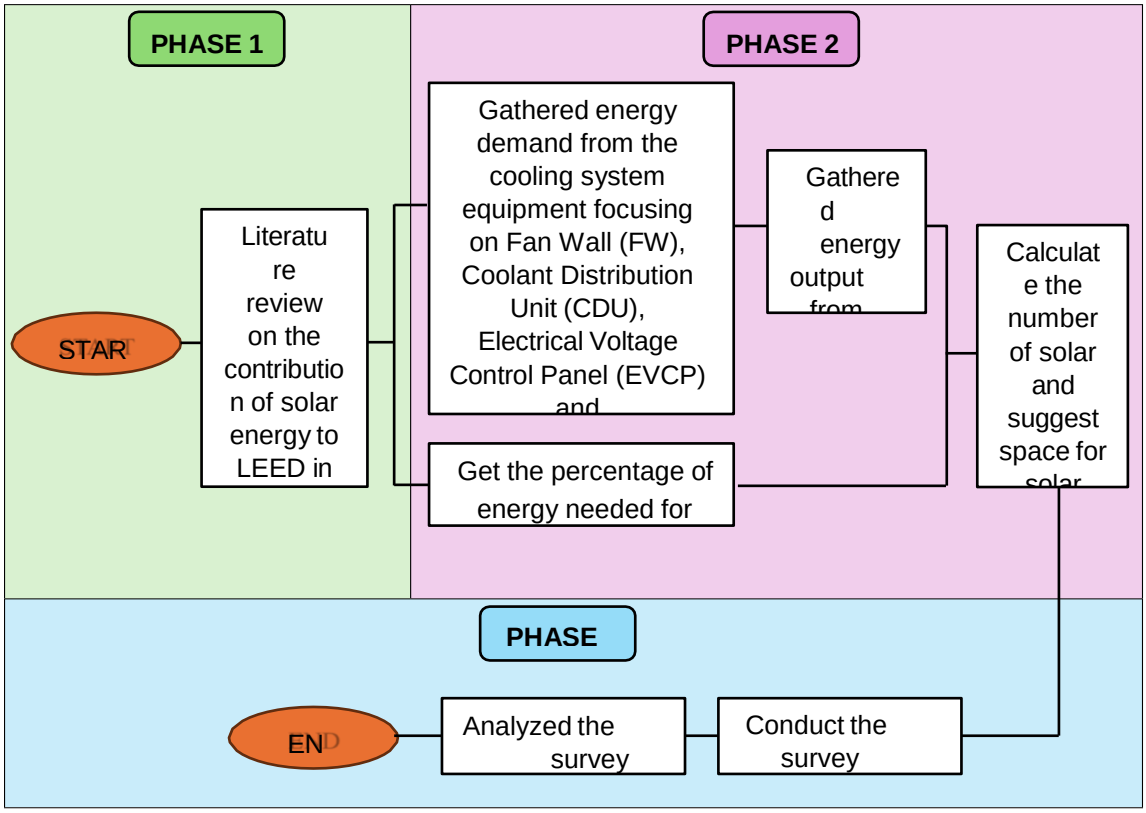


Figure 2: Research framework

First and foremost, literature review on the contribution of solar energy to LEED in high energy buildings is done to explore how solar energy align with the principles and credits in the certification framework. Moreover, it helps to understand the role of solar energy adaption and the way it supports the sustainable building practices. In addition, the literature review provides the insight on the category that benefit from renewable energy usage.

Secondly, the energy demand from the cooling system equipment was gathered. The cooling system focused on Fan Wall (FW), Coolant Distribution Unit (CDU), Electrical Voltage Control Panel (EVCP) and Computer Room Air Handler (CRAH). The energy demand for each equipment is identify by reviewing the equipment straight line diagram (SLD). The current load (CL) for the equipment was gathered in an Excel sheet. Subsequently, the percentage and estimated total energy demand of the cooling system for data centre building was calculated.

Next, the energy output from the chosen solar panel was collected. The energy input and output were compared as to have the suggestion on the number of solar panels that needed to be installed, and the land required to have the required solar farm. Based on this, the location of the solar farm is suggested. The estimation ensures the proposed solar energy can effectively support the energy demand of the cooling system.

Finally, the survey questionnaire is conducted to identify the challenges in adopting solar energy. It provides the insight from 50 respondents from the engineering technical personnel from the study area. Overall, the findings helped in identify the barrier that may affect the implementation of solar energy solutions in high-energy building.

3.0 RESULTS AND DISCUSSION

3.1 Solar Energy in LEED

LEED is the recognized green building certification that offers the structured framework for designing, constructing and operating buildings that prioritize energy efficiency, sustainability and environmental responsibility. In order to achieve LEED certification, the buildings must get the credits across the category and achieve the levels from Certified to Silver, Gold and Platinum. The latest version is LEED v4.1 which especially highlights need to reduce the carbon footprint, lower the operational costs and improving the indoor air quality. By implementing solar energy, the Sustainable Sites (SS) and Energy and Atmosphere (EA) category points can be earned. Overall, all the strategies align with the mission on promoting the environmental responsible buildings that ensure the long-term cost savings.

3.1.1 Sustainable Sites Category

The Sustainable Sites (SS) category in LEED certification aims to decrease the building's carbon footprint by promoting the responsible land use and preserving the ecosystem health. It highlights the minimizing of site disturbance, while enhancing biodiversity and improving water and soil management. The total point in this category is 10 points. Moreover, one of the main goals is to emphasize the protection of greenfield areas and restoration of previously developed sites using native or adaptive vegetation. Therefore, the integration of the SS category elements could set the foundation for integrating renewable energy technologies such as solar power into sustainable sites strategies. Table 1 shows the credit under SS category that contribute LEED certification points when solar energy is integrated.

Table 1: SS Category Credits Benefitting From Solar Energy Implementation

No	Credits	Explanation
1	Protect or Restore Habitat	LEED encourage the developers to protect at least 40% of the greenfield areas and restore 30% of the previously developed land by integrating the vegetation to supports biodiversity (Kaiser, 2021). Solar farm on the brownfields supports these goals. This approach helps in maintaining the ecological balance and support the wildlife habitat conservation.
2	Rainwater Management	The solar energy also pays roles in supporting the rainwater management credits under SS category. Solar panel can assist by directing the rainwater into the harvesting systems for reuse.
3	Heat Island Reduction	Solar panels give shades and reduce the surface heat absorption. This helps in lower the local temperature and energy demand. It also supports the climate resilience.

3.1.2 Energy and Atmosphere Category

The Energy and Atmosphere (EA) category in LEED certification prioritize the energy efficiency, decreasing in greenhouse emissions and the promotion of renewable energy in building projects. The total point in this category is 33 points. The goals of this category are to overcome the industry standard energy performance. Additionally, it ensures proper commissioning, verification of energy systems and supports energy monitoring. As a result, improved energy performance in a building not only will reduce the environmental impact but contribute directly to reduce the carbon footprint. Table 2 shows how solar energy supports EA category in LEED certification.

Table 2: EA Category Credits Benefiting from Solar Energy Implementation

No	Credits	Explanation
1	Optimize Energy Performance	This credit focus on decreasing the overall energy demand while maximizing clean energy output. The implementation of solar panel will help in building the greener future by lowering the emissions (Chen, et al., 2023). The implementation of energy-efficient design practices leads to both environmental and financial benefits.
2	Enhanced Commissioning	This credit ensures the energy systems are installed, tested and operated according to the design. The solar energy system must be properly commissioned for optimal performance. The early issue detection reduces the long-term operational costs and supports sustainable energy use.
3	Renewable Energy	LEED certification promotes on-site renewable energy to reduce the reliance on traditional energy supply. The solar

	Production	panel integration allows the building to allow the building to generate their own clean electricity. Battery storage systems are essential to ensure a continuous energy supply, enhance energy independence and meeting green building standard.

3.2 Estimated Energy Input and Output

The second objective if this study is to access the energy required at the study area and to propose appropriate solar energy solutions to meet those needs. From the straight-line diagram (SLD), the energy input from the designated equipment can be found. The energy input from the designated equipment is shown in Figure 3.

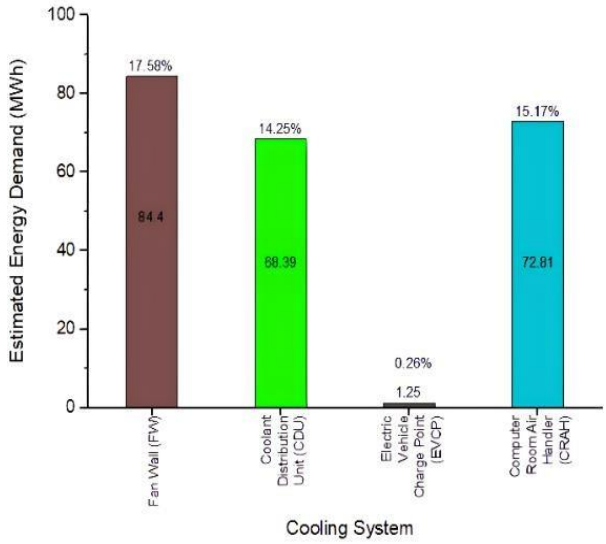


Figure 3: Estimated energy for cooling system

The percentage of energy input focusing on Fan Wall (FW), Coolant Distribution Unit(CDU), Electric Vehicle Charge Point (EVCP) and Computer Room Air Handler (CRAH) is calculated to identify the percentage of energy used by the cooling system. The FW consumes 84.4 MWh while CDU uses 68.39 MWh. The EVCP consume 1.25 MWh and CRAH accounts for 72.81 MWh. Altogether, this equipment contributes to total energy demand of 226.85 MWh. It represents 47.27% of the entire data centre's estimated energy consumption.

Next, the energy generated from the solar panel was identified. The solar panel from Trinasolar is suggested to generate the energy. Table 3 shows the details of the suggested solar panel. The solar panel selected to utilize the building is the Vertex N Bifacial Dual Glass Monocrystalline Module. Each panel generated 0.000605 MW of power which produce approximately 0.01452 MWh of energy. A total of 23500 modules are proposed to meet the energy demand as it is capable to generate 341.22MWh of clean and renewable energy. Therefore, it shows that the system has the potential to support the high energy requirements of the data centre.

Table 3: Suggested energy generated by solar panel

Type	Vertex N Bifacial Dual Glass
Power Generated (MW)	0.000605
Energy Generated (MWh)	0.01452
No. of Component	23500
Total Energy Generated (MWh)	341.22
Area of 1 Nos Solar Panel (m^2)	2.70
Area Required (acre)	15.7

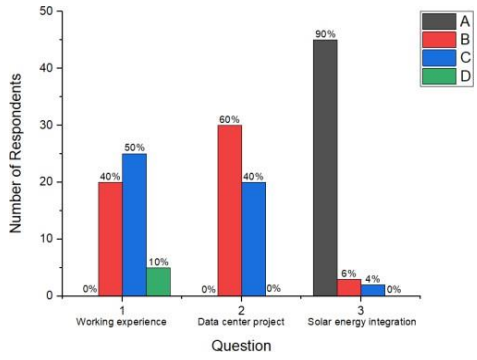
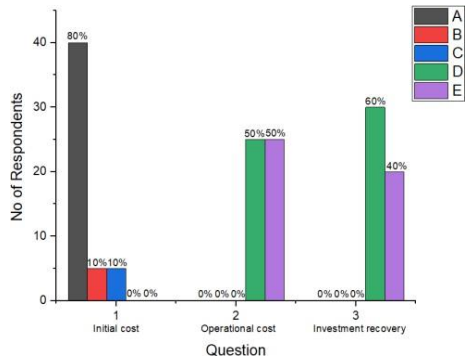
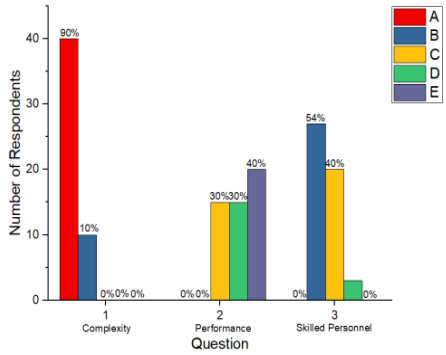
It shows that 71% of the two-storey data centre buildings energy demand can be covered by 23500 nos of solar panel. To achieve this, a solar farm with 15.7-acre area is required. Due to the rooftop being fully occupied by the equipment, solar panel installation at the roof is not feasible. Instead, it is suggested that the solar farm be developed at the back of each building where land is available as shown in Figure 4. The entire site consists of eight building, with three are under construction and five still pending development.

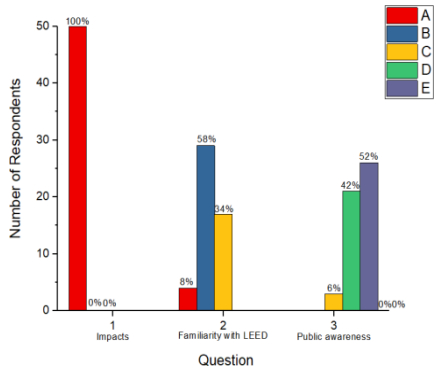
Figure 4: Suggested location of the solar farm

3.3 Challenges

A set of questionnaires was distributed to 50 respondents to gain the insight on the challenges in integrating solar energy in high energy buildings. The questions can be referred at Appendix 1. The targeted respondents included engineers such as site engineers, project engineers, testing and commission engineers and QAQC engineers. The challenges can be seen from three perspective which is cost, complexity and awareness. As shown in Table 4, the questionnaire results reflect these areas of concern.

Table 4: Questionnaire Results

Section	Result	
Demographic		The respondents have moderate experience in the construction industry with 40% having 3-5 years. The involvement in data center project is strong with 60& involves in 1-2 projects. However, 90% of the respondents never involved in solar energy integrated project. This result shows that the need for greater exposure in renewable energy.
Cost		80% of the respondents agree that the initial cost of the solar panel as very expensive. Despite this, all agree that solar energy helps in reducing long-term operational costs. Furthermore, the respondents confident in recovering the cost of investment over time. Overall, while high primary cost is a concern, the long-term savings and cost recovery make solar energy a financially solution.
Complexity		90% of the respondents see the solar integration as very complex. Despite this, 70% insight view the system can perform well and very well. However, 54% noted a shortage of technical personnel in solar energy sector. These findings reflect the needs for technical support to overcome integration challenges and support wider solar adaption.

Awareness		All respondents agreed that awareness will impact the adoption of solar energy. However, only 8% were familiar with LEED certification which shows the knowledge gap in green building standard. In addition, 94% says the public awareness is very important. These results highlight the need for targeted education and outreach to improve understanding of solar energy in LEED certification.

From the result, all respondents agreed that solar energy have the full potential to replace the traditional energy sources in the future. It reflects that there is a strong capability of the renewable energy to meet the long-term demands. Additionally, all the respondents show the optimism about the future of solar energy within their industry. This further demonstrates strong support and confidence in the growth and the impact of solar energy in a building.

In summary, this survey findings shows that while the respondents have the moderate experience in construction and data centre projects, there is a significant lack of exposure to solar energy integration. Even though with the concern of high initial costs, there is a strong confidence in the long-term financial benefits and cost recovery of solar energy systems. However, the system complexity and limited technical expertise highlight the need for better support and training in renewable energy sector. Overall, the respondents strongly believe in the future potential of the solar energy by showing the optimism and support for the adoption in high-energy buildings.

4.0 CONCLUSION

The integration of solar energy contributes to achieving LEED certification by supporting both SS and EA category. It promotes the ecological protection, reduce the heat island effect and support sustainable water management under SS category. Furthermore, in the EA category, solar energy implementation helps in optimize energy performance, ensure proper system commissioning and promotes renewable energy use. These contributions align with LEED's goals of decreasing the carbon emissions, improving building efficiency and supporting long-term environmental sustainability. Therefore, solar energy is an impactful plan green building standard.

In another hand, the energy analysis shows that the proposed 23500 nos of solar panels can approximately contribute to 71% of the data centre building energy demand which cover the cooling system. By installing Vertex N Bifacial Dual Glass Monocrystalline Modules, a total of 341.22 MWh of clean energy can be generated. As rooftop installation is not feasible due to the equipment constraints, a 15.7-acre solar farm is proposed at the back of each building. This result reflects that there is a strong potential to support the facility's sustainability goals and reduce the reliance on non-renewable energy sources.

The findings revealed that while the respondents have moderate experience in construction and data centre projects. They also have the lack exposure in solar integration. Despite 80% respondents citing high initial cost, 100% agreed that the solar energy can reduce the long-term operational expenses. Moreover, the respondents also showed the strong optimism as they believe that solar energy could replace the traditional sources in the future. However, 90% viewed that

the implementation is very complex and 54% state that there is lack of skilled personnel. Therefore, this result reflects the indicate high potential of solar adoption with essential support and training for effective implementation.

Overall, the study confirmed that solar energy is a sustainable solution for high-energy buildings which contribute to LEED certification and environmental goals. The awareness, technical personnel and financial support are important to overcome the current barriers. By having a public education and professional training, the knowledge gap can be narrowed. Furthermore, the research aligns with the Sustainable Development Goal 7: Affordable and Clean Energy. Therefore, it is recommended that the future projects to prioritize the renewable energy integration in order to decrease the carbon footprint and promote the green infrastructure growth.

APPENDIX 1

SURVEY SUESTIONNAIRE

How long have you been working in the construction or energy sector?

(a) Less than 1 year
(b) 1-2 years
(c) 3-5 years
(d) More than 5 years

How many data centre projects have you worked on?

(a) None
(b) 1-2 nos
(c) 3-5 nos
(d) More than 5 nos

How many projects have you worked on involving solar energy integration?

(a) None
(b) 1-2 nos
(c) 3-5 nos
(d) More than 5 nos

COST

1. What is your perception of the initial cost of solar energy systems?
(a) Very expensive
(b) Expensive
(c) Neutral
(d) Affordable
(e) Very Affordable

2. Do you think solar energy reduces long-term operational costs?
(a) Strongly disagree
(b) Sightly disagree
(c) Neutral
(d) Agree
(e) Strongly agree

3. How confident are you about recovering the investment in solar energy within the expected timeframe?

(a) Not confident at all
(b) Slightly confident
(c) Neutral
(d) Confident
(e) Very confident

CHALLENGES

1. How would you rate the complexity of integrating solar energy systems into existing building infrastructure? (a) Very complex
(b) Complex
(c) Neutral
(d) Simple
(e) Very simple

2. How well do you think solar energy systems perform in buildings with high energy demand such as data centres building?
(a) Very poor
(b) Poor
(c) Neutral
(d) Well
(e) Very well

3. How would you rate the availability of skilled technical personnel for solar energy system installations and maintenance?
(a) Very limited
(b) Limited
(c) Neutral
(d) Sufficient
(e) Very sufficient

AWARENESS

1. Do you think awareness about solar energy impacts its adoption in projects?
(a) Yes
(b) No
(c) Not sure

2. Are you familiar with the Leadership in Energy and Environmental Design (LEED) certification process? (a) Yes
(b) No
(c)Somewhat

3. How important is public awareness in driving solar energy adoption?
(a) Not important
(b) Slightly important

(c) Moderately important
(d) Important
(e) Very important

RECOMMENDATION AND FUTURE SCOPE

1. Do you believe solar energy has the potential to fully replace traditional energy sources in the future? (a) Yes
(b) No
(c) Not sure

2. Are you optimistic about the future of solar energy in your industry?
(a) Yes
(b) No
(c) Not sure

5.0 ACKNOWLEDGEMENT

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Intuitive Application For QLASSIC Scoring And 3d Model With Defect Visualization To Revolutionize QAQC Practices In Construction (IAQ3D)

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ABSTRACT

In construction, traditional quality assurance and quality control (QAQC) processes often depend on manual QLASSIC scoring and limited visual communication, leading to human error, data inefficiency, and delays in defect rectification. This study introduces IAQ3D, an intuitive mobile application designed to digitalize and enhance QAQC practices by combining automated QLASSIC scoring with 3D model-based defect tagging. The prototype was developed using Flutter, and the 3D building layout was created in SketchUp to simulate actual project units. The main objective is to evaluate the effectiveness of IAQ3D in improving QAQC workflows. A structured questionnaire based on four constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Behavioural Control (PBC), and Behavioural Intention (BI), was distributed to 15 construction professionals from the OSK Construction at the LEA by the Hills project site. Data were analysed using SPSS through descriptive statistics and the Wilcoxon Signed Rank Test. Results showed high mean scores above 5.7 for all constructs on a 6-point Likert scale. The statistical test confirmed significant agreement, and the Cronbach's Alpha score of 0.755 indicated acceptable internal consistency. Findings show that IAQ3D is effective in improving QAQC accuracy, tracking, and communication. This application supports the industry's move toward digital solutions, offering a reliable tool for better quality control in construction projects.

Keywords: Application, QAQC, 3D Model Defect Visualization, IAQ3D

1.0 INTRODUCTION

Quality In today's construction industry, ensuring consistent quality is crucial for developers aiming to meet customer expectations and stay competitive. To standardize and benchmark workmanship quality, the Construction Industry Development Board (CIDB) of Malaysia introduced the Quality Assessment System in Construction (QLASSIC), guided by the Construction Industry Standard (CIS 7). QLASSIC enables systematic evaluations of architectural, structural, and M&E works, supporting contractors in tracking performance and identifying areas for improvement (CIDB, 2020). However, the practical implementation of QLASSIC still heavily relies on manual scoring via spreadsheets and static reporting methods, often resulting in human error, delays in defect rectification, and inefficient communication between QAQC teams and subcontractors (Sohail & Cavill, 2021; Waziri, 2016).

Recent advancements in digital tools, particularly mobile applications and 3D visualization, have shown promise in addressing these limitations. Integrating such technologies into QAQC practices can significantly enhance inspection accuracy, streamline documentation, and promote real-time collaboration among stakeholders (Rahman et al., 2021; Sundaram & Zeid, 2023). The Fourth Industrial Revolution (IR 4.0) has further accelerated this digital shift, promoting automation, real-time data tracking, and smart defect management through tools like Building Information Modelling (BIM) and AI-driven applications.

This study introduces IAQ3D – an Intuitive Application for QLASSIC Scoring and 3D Defect Visualization – developed as a mobile-based prototype to support construction QAQC teams. The application integrates automated scoring based on CIS 7 guidelines, a 3D model interface for defect tagging, and real-time defect tracking to streamline inspections. Tested at LEA by the Hills, a condominium project by OSK Construction, the application was evaluated for usability and effectiveness through structured user feedback.

The primary aim of this research is to develop a mobile application that addresses inefficiencies in current QAQC practices. The study specifically focuses on identifying common issues in manual QAQC implementation, developing a working prototype integrating QLASSIC scoring and 3D visualization, and evaluating the app's usability and effectiveness through questionnaire-based analysis. By providing a practical digital solution, IAQ3D aligns with the goals of sustainable construction under SDG 9.4 (infrastructure upgrade for sustainability) and SDG 11.3 (inclusive, sustainable urbanization), offering a transformative approach to quality management in Malaysia's construction sector.

2.0 METHODOLOGY

Figure 1 illustrates the research framework used in this study, which is divided into three phases: planning, development, and evaluation. The process begins with identifying the problem, followed by a literature review and data collection, including internal QLASSIC assessments from the LEA by the Hills project. Based on the findings, a prototype of the IAQ3D application was designed and developed using Flutter, with 3D models built in SketchUp. After testing, the application was refined to meet functional requirements. In the final phase, the system was evaluated through a user-based questionnaire focused on perceived usefulness, ease of use, behavioural control, and intention. The collected data was analyzed to validate the application's effectiveness in improving QAQC processes.

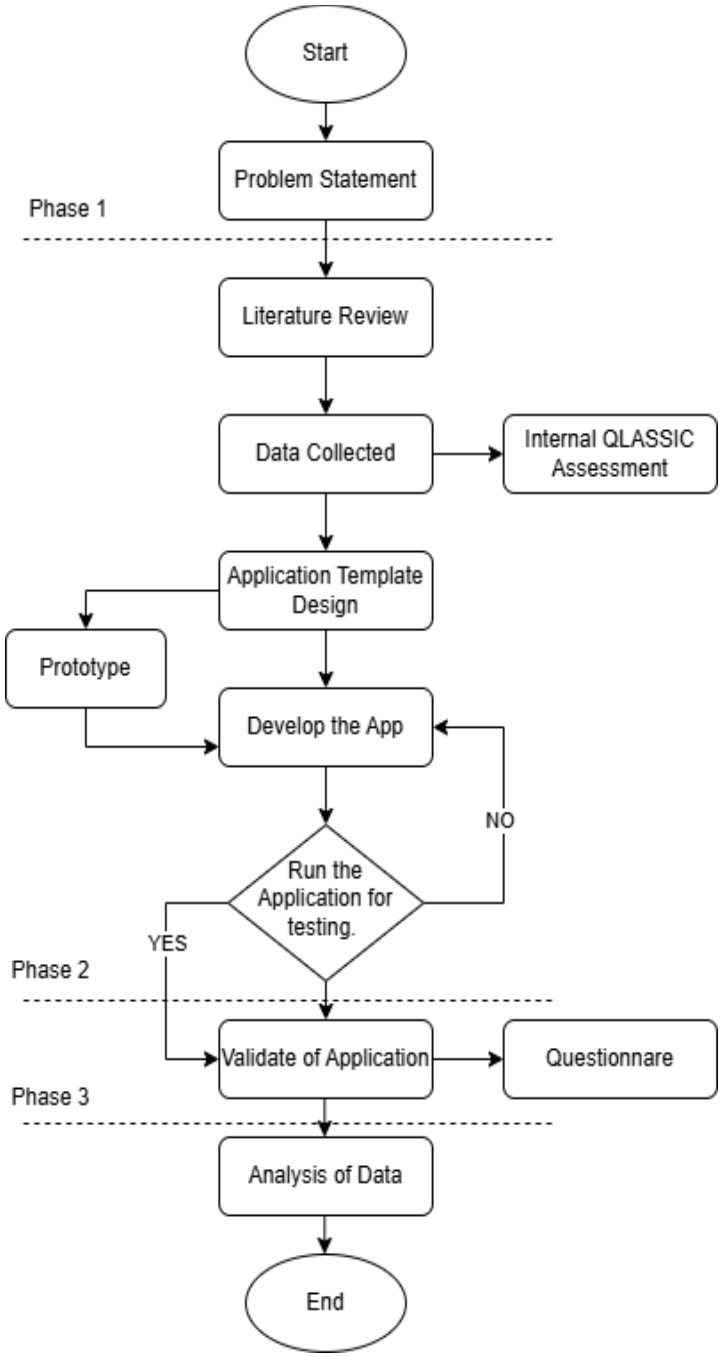
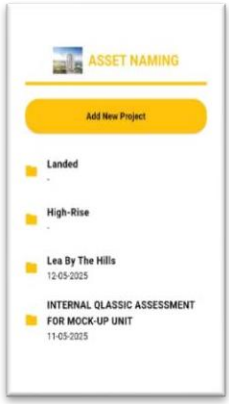


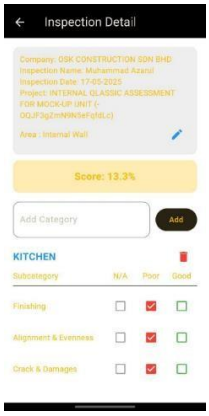
Figure 1: Methodology flowchart

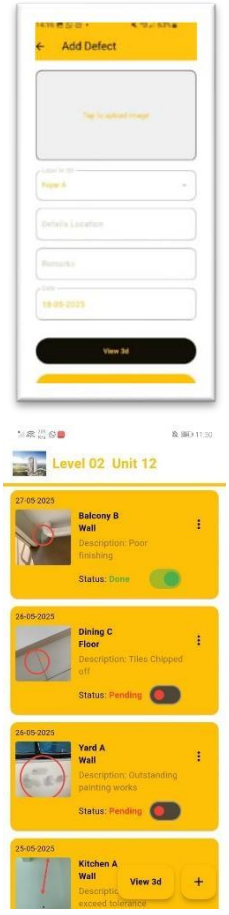
2.1 System Design and Development

The IAQ3D application was designed based on the system requirements identified during the planning phase. The development process focused on building a mobile app that supports automated QLASSIC scoring, defect tagging, and 3D model integration. Flutter was used for cross-platform development, while SketchUp was used to create the building layout models. This phase also involved UI/UX design using Figma to ensure the app was user-friendly and suitable for field inspection tasks.

Table 1: Prototype and explanation of IAQ3D

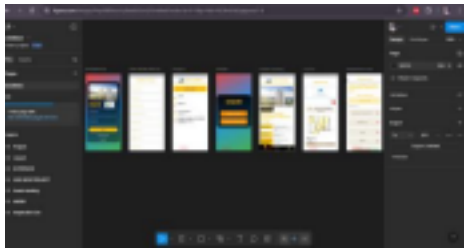
Prototype	Justification
	1. The IAQ3D interface prototype includes two selectable options for users: • Internal QLASSIC • 3D model with Defect Rectification
	2. Project List Interface: This section displays a list of ongoing projects, allowing users to easily access and manage QAQC tasks for multiple construction sites.
	3. Detail Project: The prototype interface for IAQ3D showcases the Project Details.

	4. Upload File Layout: The purpose is enables users to upload project layout files, such as floor plans or structural designs, for seamless integration into the QAQC process.
	5. Purpose Inspection List: Displays a comprehensive list of inspection tasks for a specific project.
	6. Tick for Scoring: The purpose is allowing users to input QLASSIC scores by ticking predefined criteria based on inspection outcomes.

	7. 3D Viewer Screen: a) Prepare 3D model (Sketchup). b) Integrate the Model into the Application (Use a 3D visualization engine 'Flutter' to load and render the model in your application. c) Labelled Zones: The 3D model includes labelled locations (e.g., "Foyer A", "Unit 1B", "Corridor") to help users accurately identify and tag defect positions.
	8. Defect Visualization and Tracking a) Image Upload – Users can take or upload a defect photo on the spot. b) Label in 3D – Users select the location of the defect from a dropdown menu mapped to 3D zones (e.g., Foyer, Corridor, Unit 1B). c) Location Details – Allows detailed manual entry of the physical defect location. d) Remarks – Users can enter additional notes or rectification instructions. e) Date Field – Automatically captures the current inspection date or allows manual input.

2.2 Tools and Platforms Utilized for Design, Development, and Evaluation of IAQ3D

Table 2: Tools and Platforms Used in the Development of IAQ3D

Item	Purpose
 Source: Developed by Author using Figma (2025)	Figma used to design the user interface (UI) layout of the app
Source: Developed by Author using SketchUp (2025)	SketchUp used to develop 3D models of the residential unit
Source: Flutter framework, https://flutter.dev/	Flutter used as the framework for developing the mobile application
Smartphone	Used to test and run the IAQ3D app in real construction field

Source: Google Forms platform, https://forms.google.com/	Used to create and distribute the user evaluation questionnaire refer Appendix A

Table 2 outlines the primary tools and platforms utilized during the system design and evaluation phases. Figma supported UI prototyping to ensure a clean and intuitive user interface. SketchUp was used to model the unit layout in 3D for integration into the app. The IAQ3D app was built using Flutter for cross-platform functionality, with testing conducted on an Android smartphone. Finally, Google Forms facilitated efficient data collection for user feedback

2.3 Product Testing

A structured questionnaire was used to evaluate the effectiveness of the IAQ3D application from the perspective of construction professionals. The questionnaire was designed to gather reliable feedback on user experience, functionality, and the app's impact on QAQC processes. It was distributed to 15 selected respondents involved in the LEA by the Hills project, including QAQC inspectors, site supervisors, and project engineers. Their input was essential in assessing the practicality and usability of the application in a real construction environment.

3.0 RESULTS AND DISCUSSION

This section presents the findings from the implementation and testing of the IAQ3D application, based on the study's key objectives. The first objective was to identify problems in current QAQC practices, particularly in QLASSIC scoring and defect rectification. The second objective was to develop a mobile application that integrates automated QLASSIC scoring and 3D model-based defect visualization to address those challenges. Finally, the third objective aimed to evaluate the effectiveness of the developed application in improving QAQC processes. Data was collected from 15 targeted respondents through a structured questionnaire. The analysis includes demographic data, reliability testing, descriptive statistics, and nonparametric testing to assess how well the application performs in real construction settings.

3.1 Demographic Profile

The researcher conducted a quantitative survey through a questionnaire with 15 on-site respondents to identify the problems in the current QAQC processes and to evaluate the effectiveness of the developed application, particularly in QLASSIC scoring and defect rectification, within construction projects. To analyse the demographic data of this study, the SPSS software was used to construct frequency tables. Table 3 shows the frequency of each

gender was computed. The frequency data indicates that the vast majority of respondents were male, with 11 out of 15 participants (73.3%), while females accounted for only 4 respondents (26.7%). This distribution reflects the male-dominated nature of the construction industry, particularly in QAQC and site-related roles.

Table 3: The number of respondents by gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	4	26.7	26.7	26.7
	Male	11	73.3	73.3	100.0
	Total	15	100.0	100.0	

3.2 Reliability Test

To assess the internal consistency of the survey instrument used for both identifying current QAQC challenges and evaluating the effectiveness of the IAQ3D application, Cronbach's Alpha values were calculated based on responses from 15 participants. Cronbach's Alpha ranges from 0 to 1, where higher values indicate stronger internal reliability among related items. According to the interpretation scale by Streiner (2011), values above 0.70 are considered acceptable, while those above 0.80 indicate good internal consistency. Table 4 presents the general Cronbach's Alpha interpretation scale used as a benchmark in this study.

Table 4: Cronbach's Alpha Interpretation Scale (Streiner 2011)

Cronbach's Alpha	Interpretation
More than 0.90	Excellent
0.80-0.89	Good
0.70-0.79	Acceptable
0.6-0.69	Questionable
0.5-0.69	Poor
Less than 0.59	Unacceptable

The results indicate an overall Cronbach's Alpha value of 0.755, demonstrating acceptable internal consistency across the survey items. Table 5 summarizes the reliability statistics related to the section of the questionnaire aimed at identifying QAQC challenges.

Table 5: Reliability Test Results for QAQC challenges

Statistic	Value
Number of Items	7
Number of Respondents	15
Cronbach's Alpha	0.755 (Acceptable)

In addition to identifying QAQC issues, the survey included items designed to evaluate the IAQ3D application's usefulness and user experience. These items were grouped into four constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Behavioural Control (PBC), and Behavioural Intention (BI). Table 6 shows the Cronbach's Alpha values for each of these constructs. All four values exceed the 0.70 threshold, ranging from 0.745 to 0.781, confirming acceptable reliability across the evaluation section of the instrument.

Table 6: Reliability Test Results – IAQ3D Application Evaluation

Construct	No. of Items	Cronbach's Alpha	Interpretation
Perceived Usefulness (PU)	5	0.755	Acceptable
Perceived Ease of Use (PEU)	5	0.745	Acceptable
Perceived Behavioural Control (PBC)	4	0.768	Acceptable
Behavioural Intention (BI)	4	0.781	Acceptable

These results validate that the questionnaire was both statistically reliable and well-suited for capturing user perceptions related to the effectiveness of the IAQ3D application, in line with the commonly accepted threshold for internal consistency (George & Mallery, 2003).

3.3 One-Sample Nonparametric Test

To evaluate user perceptions regarding the effectiveness of the IAQ3D application, a One Sample Wilcoxon Signed-Rank Test was conducted. Given the ordinal nature of the 6-point Likert scale and the relatively small sample size (n = 15). The test compares the sample median to a neutral hypothesized median of 3.5, representing neither agreement nor disagreement. The analysis focused on the Perceived Usefulness (PU) construct, as it reflects the overall practical impact of the application in a QAQC setting. A composite average score (PU_avg) was calculated across five items for each respondent. The Wilcoxon test revealed a median value

of 5.80 and a mean of 5.71, both substantially higher than the neutral threshold. The standard deviation of 0.3615 indicates consistent responses among users. The outcome of the statistical analysis is presented in Figure 2 and Figure 3

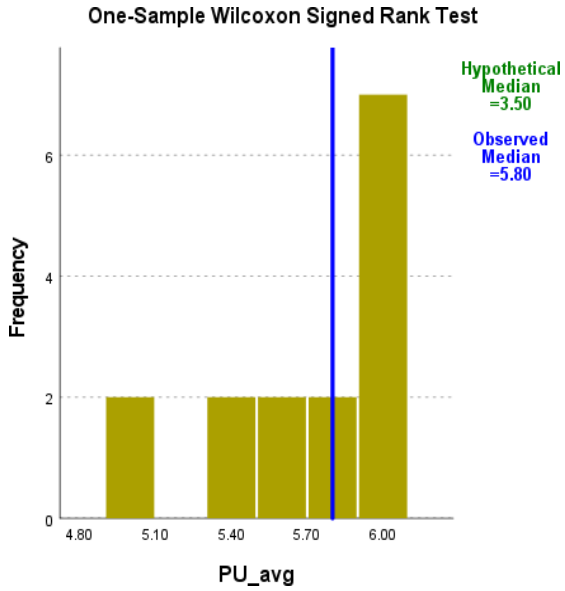


Figure 2: Bar chart of the Wilcoxon Signed-Rank Test for Perceived Usefulness

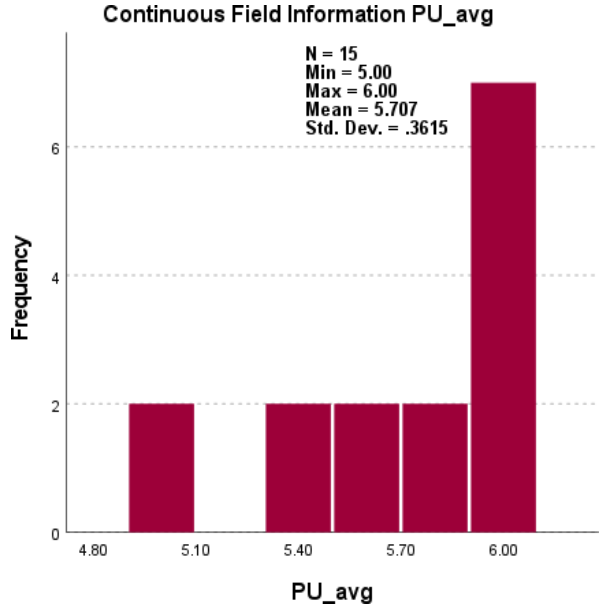


Figure 3: Descriptive statistics distribution of PU_avg

These results confirm that users found the IAQ3D application highly useful in improving QAQC processes. Specifically, the integration of automated QLASSIC scoring was highlighted as a major strength. By eliminating the need for manual calculation, the app significantly reduces the likelihood of scoring errors and speeds up the inspection process. In addition, the inclusion of 3D defect visualization allows for faster defect identification and rectification, contributing to more accurate and efficient QLASSIC assessments on-site.

4.0 CONCLUSION

This study addressed limitations in traditional QAQC processes by developing and evaluating the IAQ3D mobile application, which integrates automated QLASSIC scoring with 3D model based defect visualization. The application was designed and tested to streamline inspections, reduce manual errors, and improve communication on construction sites. Feedback from 15 construction professionals indicated strong agreement regarding the app's effectiveness. All core constructs including Perceived Usefulness, Ease of Use, Behavioural Control and Intention to Use scored above 5.7 on a 6-point Likert scale. Statistical analysis using the Wilcoxon Signed-Rank Test confirmed that users significantly favored the digital approach over traditional manual methods. The 3D model with defect tagging feature was particularly impactful. It allowed users to locate, document and resolve defects visually, leading to faster rectification and improved coordination between QAQC teams and subcontractors. This contributed to more accurate QLASSIC scoring and enhanced construction quality.

In addition to improving on-site efficiency, IAQ3D supports broader sustainable development objectives. It aligns with SDG Target 9.4, which calls for upgrading infrastructure and adopting environmentally sound technologies to promote sustainable industrial practices. By reducing manual scoring errors and improving defect management, IAQ3D contributes to more sustainable and efficient construction workflows. Furthermore, the project also supports SDG Target 11.3 by enhancing the quality and sustainability of urban construction through better planning, inspection, and rectification practices. By promoting digital transformation in QAQC processes, IAQ3D advances inclusive and sustainable urbanization and strengthens construction quality in residential developments. Overall, IAQ3D provides a practical and user friendly solution that advances QAQC practices through automation and interactive defect visualization, paving the way for smarter and higher-quality construction outcomes.

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Machine Learning-Based Defect Prediction And Data Analysis With Power BI In Construction

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ABSTRACT

This research delves into the development and implementation of predictive models for managing construction defects, utilising historical data by QAQC inspection from the Dedaun Rimba, Kwasa Damansara project. In construction management, defect inspection is a very important tactic used in the post-construction stage. A mock-up unit was inspected and assessed in terms of building condition. Assessment findings were consolidated with those of defective groups based on the criteria of CIS 7: 2021 to determine the defect type, building component, and construction field in which defects often occur. The primary focus of this study is to investigate the application of advanced machine learning techniques for predicting and classifying construction defects, thereby enabling more efficient defect management in the construction industry. The study employs two cutting-edge machine learning algorithms: Support Vector Machine (SVM) and Adaptive Neuro-Fuzzy Inference System (ANFIS). The primary goal of this research is to enhance defect prediction accuracy by offering a proactive approach to managing construction quality. The predictive models are developed and tested using MATLAB, with performance rigorously evaluated using the Root Mean Square Error (RMSE) metric to ensure the models' effectiveness in real-world applications. To maximise the practical value of the findings, the results are visualised using Power BI as offering an interactive dashboard that provides key insights into subcontractor performance and highlights those with higher defect rates. Additionally, the dashboard displays predicted and actual defect types to help identify recurring quality issues and enable better decision-making for construction quality improvement.

Keywords: Machine learning, defects, quality, data visualisation, prediction

1.0 INTRODUCTION

In construction management, defect inspection is a very important tactic used in the post construction stage. Defect inspection aims to find problems in the as built or analyse construction quality phase that deviate from the design standards or specifications. Defects in buildings are one of the most significant factors affecting building projects, with direct impacts on project quality and schedule, in addition to their influence on end-user satisfaction if not discovered before the final handover of the building to the client. Defects are of immense significance, and they present a fertile ground for researchers to delve deeper into the underlying causes in order to offer a more comprehensive understanding of how to prevent them in future projects. However, a few defects are detected during inspection and reporting documentation. The need to perform rework not only consumes additional time but also adversely impacting quality and delivery timelines. Rework due to defects is often labour-intensive and disrupts construction progress, as it requires revisiting completed phases of work to address issues that should have been prevented or resolved earlier. For this Dedaun Rimba,

Kwasa Damansara project site they have a standard and specifications that need to follow which is Quality Assessment System in Construction (Qlassic). Qlassic is a standardized method developed by the Construction Industry Development Board (CIDB) Malaysia to measure and evaluate the quality of workmanship in building construction projects (CIS 7:2021). Despite the fact that numerous studies have delved into the causes of construction defects, highlighting factors such as poor workmanship, design errors and inadequate supervision. For example, Arman et al. (2022) identified critical causal factors such as inadequate design and specifications, inadequate communication within the project environment and subpar performance of the project management team. In the same vein, Jingmond and Agren (2015) conducted a study that underscored the fact that the primary causes of defects are rooted in organisational deficiencies. This suggests that enhancements can be made at the strategic and management levels of projects. In addition, Anwar Hussain and Saquib (2021) conducted research that investigated defects throughout the entire building lifecycle. Their findings indicate that the construction and post-occupancy phases are the primary contributors, including inadequate maintenance and subpar workmanship.

To overcome these limitations, machine learning (ML) presents a modern and intelligent solution. ML algorithms can process extensive datasets and uncover patterns that are not easily detected through manual analysis. This paper indicates that ML methods are widely used in the prediction of the various fields but not in defects at site. For instance, Inthara et al. (2023) successfully applied a hybrid ML model combining Principal Component Analysis and Multilayer Perceptron to predict construction quality based on defect inspection data and achieving over 91% accuracy. Similarly, Zhang and El-Gohary (2020) employed a combination of association rule mining and Bayesian networks to assess defect risks across multiple construction sites. In the field of deep learning, models like InceptionV3 and ResNet50 have been used effectively to classify concrete surface defects such as cracks and spalling with high accuracy (Ekanayake et al., 2023).However, several researchers have evaluated the performance of ML technology in classifying the severity of construction defects from the perspective of workmanship factors. The purpose of this study is to identify and develop the performance of different ML methods in classifying the severity of construction defects at Kwasa Damansara Project. Based on an efficient predictive model, results analysis can reveal future predictions and visualizations with Power BI for the final quality outcome.

Therefore, the objective of this study is to identify construction defects based on inspection of the mock-up unit at the Kwasa Damansara site from historical defect data. By training the Support Vector Machine (SVM) and Adaptive Neuro-Fuzzy Inference System (ANFIS), this research aims to develop a construction defect prediction model in MATLAB with identify the most effective prediction model using Root Mean Square Error (RMSE) as the primary metric. The significance of this study to analyse defect prediction results through an interactive Power BI dashboard that highlighting actual versus predicted defects while identifying recurring quality issues for proactive construction quality management.

3.0 METHODOLOGY

The process commences with the identification of the primary issue frequent defects in construction and the collection of pertinent historical defect data. The Dedaun Rimba, Kwasa Damansara project was the source of the data utilised in this investigation. The prediction model was constructed on the basis of Figure 1 that shows framework of this study.

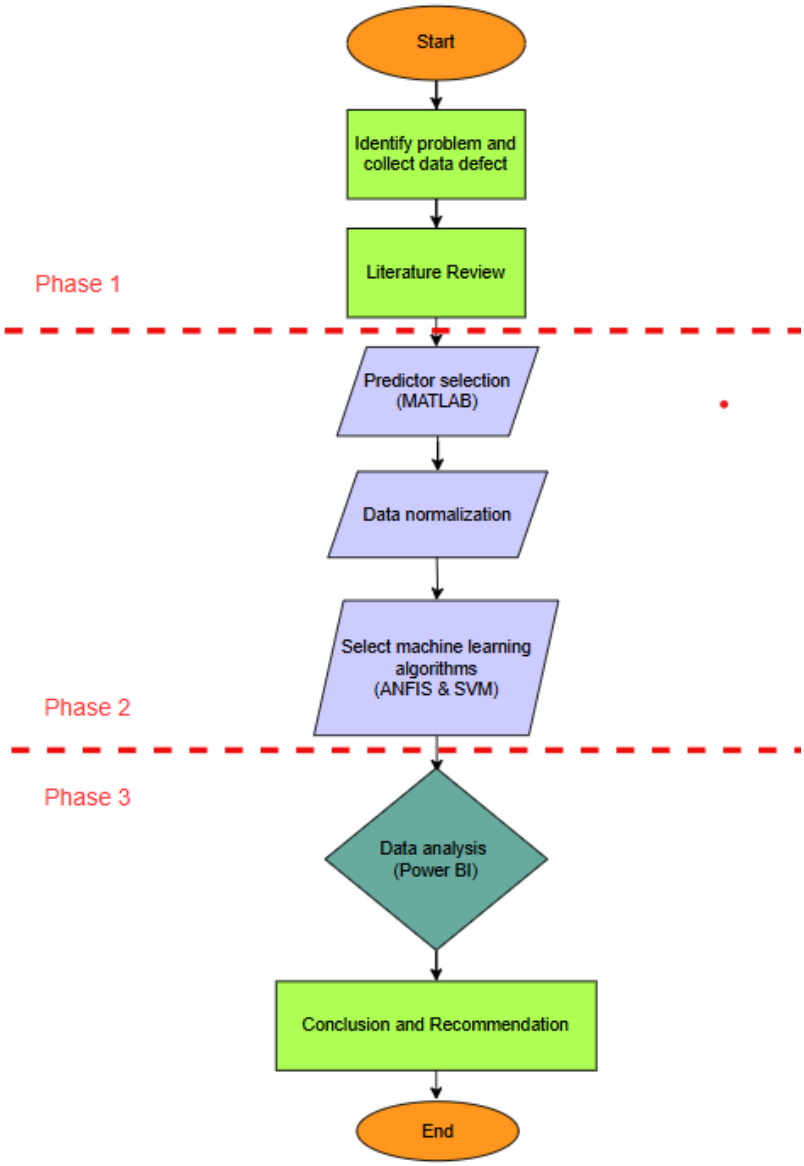


Figure 1: Research Methodology Flowchart

3.1 Data Collection

The dataset used in this study was collected from historical defect data at an actual site. The defect data includes types of defects, responsible parties, and defect frequency. Data collection for predictive defect analysis was conducted using historical defect data from the Dedaun Rimba project at Kwasa Damansara, which has already undergone inspection by QAQC. Based on the historical data, a few researchers have used SVM and ANFIS as model predict in MATLAB. Zhang & Li, (2023) constructed a support vector regression (SVR) model to predict construction durations using data from 75 projects. The features considered included contract type, project scale, and contractor classification. The SVR model achieved lower error rates than traditional regression models, demonstrating SVM's potential for time sensitive prediction tasks in construction management. Furthermore, ANFIS has also been applied in defect risk prediction. For example, Wijayanto et al., (2022) used ANFIS to predict construction site accidents based on historical accident records and site conditions. The model helped identify patterns that were previously undetectable using statistical approaches, suggesting the potential

of ANFIS in improving safety and quality assurance in construction.

To ensure the data was suitable for machine learning development, a comprehensive pre processing procedure was performed. This began with normalize the defect data which is data normalization is a critical pre-processing step in machine learning and data analysis that involves scaling the features of a dataset to ensure they contribute equally to the model's learning process. This process is essential for improving the performance and accuracy of machine learning models. Min-max normalization scales the data to a fixed range, typically [0, 1]. The formula for min-max normalization is:

$$x' \frac{x - x_{min}}{x_{max} - x_{min}}$$

where x is the original value, X_{min} is the minimum value in the dataset, and X_{max} is the maximum value in the dataset (Bornmann, 2020). This method ensures that all features are on a similar scale, preventing features with larger numerical ranges from dominating the learning process.

3.2 Model Development

Two machine learning algorithms ANFIS and SVM were developed and evaluated to effectively handle non-linear relationships. The use of ANFIS and SVM in predicting construction defects is quite rare among researchers. For instance, a study by Somya Goyal, published in September 2021 in the International Journal of System Assurance Engineering and Management, explored the use of SVMs for defect prediction and proposed a novel filtering technique to enhance the performance of SVM-based models. This study demonstrated that SVM classifiers, including linear, polynomial, and radial basis function (RBF) kernels, significantly improved defect prediction accuracy when combined with the proposed filtering technique. Additionally, a study published in the International Journal of Research in Data Science and Engineering (IJRDASE) applied ANFIS for developing a software defect prediction model. The researchers used subtractive clustering to improve the predictive model, demonstrating that ANFIS could enhance defect prediction accuracy by effectively handling complex and imbalanced datasets.

3.3 Model Evaluation on Performance Metrics

The performance evaluation of the machine learning modes was compare through Root Mean Squared Error (RMSE). One of the main advantages of RMSE is its ability to provide a clear and interpretable measure of model accuracy, with the same units as the observed values. However, RMSE can be influenced by outliers due to the squaring of errors, which can disproportionately affect the metric. This sensitivity to larger errors can be both an advantage and a limitation, depending on the context of the model evaluation.

4.0 RESULTS AND DISCUSSION

This section presents the results obtained from the development and testing of machine learning models (SVM and ANFIS) for predicting construction defects. It also discusses the accuracy of the models and the insights gained from data visualization using Power BI. The discussion is structured according to the inspection of the mock-up unit at the Kwasa Damansara site revealed several types of defects. These defects were meticulously documented and categorized

to form a comprehensive dataset. The data collected included various defect types and the frequency of occurrence. This dataset served as the foundation for developing the prediction models.

4.1 Model Performance Result

Root Mean Square Error (RMSE) is a widely used metric to evaluate the performance of regression models. It measures the average magnitude of the errors between predicted values and actual values. RMSE is particularly useful because it gives a clear indication of how well the model's predictions match the actual data with lower values indicating better performance.

Table 1: SVM model performance

SVM Model			
Hyperparameter (Input)		RMSE	
Cross validation fold	Model	Training	Testing
5	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.75 8.31 8.09 7.89	6.77 7.31 7.07 6.95
10	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.81 7.78 7.70 7.48	6.77 7.09 7.07 6.95
15	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.50 7.80 7.54 7.54	6.77 7.14 7.07 7.03
20	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.42 7.95 7.73 7.75	6.77 7.09 7.07 7.03
30	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.61 7.74 7.59 7.50	6.77 7.14 7.07 7.03
40	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.64 7.69 7.55 7.51	6.77 7.14 6.99 6.95

50	Fine Gaussian SVM Linear SVM Quadratic SVM Cubic SVM	7.74 7.69 7.63 7.35	6.77 7.31 7.07 6.95

For the SVM model was evaluated using different cross-validation folds (5-fold and 10-fold) and various SVM models. Including Linear SVM, Quadratic SVM, Cubic SVM, Fine Gaussian SVM, and Medium Gaussian SVM. The training RMSE values for the SVM models ranged from approximately 7.31 to 7.84 across different folds and models. The testing RMSE values ranged from approximately 6.71 to 7.84, indicating the model's performance on unseen data.

Table 2: ANFIS model performance

Anfis Model			
Hyperparameter (Input)		RMSE	
Number of MF	Type of MF	Training	Testing
3 3 3 4 4 4 5 5 5 6 6 6	trimf	0.27 0.27 0.27 0.26	0.27 0.27 0.27 0.26
3 3 3 4 4 4 5 5 5 6 6 6	trapmf	0.27 0.27 0.27 0.27	0.27 0.27 0.27 0.27
3 3 3 4 4 4 5 5 5 6 6 6	gbellmf	0.27 0.26 0.26 0.26	0.27 0.26 0.26 0.26
3 3 3 4 4 4 5 5 5 6 6 6	gaussmf	0.27 0.26 0.26 0.26	0.27 0.26 0.26 0.26
3 3 3 4 4 4 5 5 5 6 6 6	pimf	0.27 0.27 0.27 0.27	0.27 0.27 0.27 0.27
3 3 3 4 4 4 5 5 5 6 6 6	dsigmf	0.27 0.27 0.27 0.26	0.27 0.27 0.27 0.26

3 3 3	psigmf	0.27	0.27
4 4 4		0.27	0.27
5 5 5		0.27	0.27
6 6 6		0.26	0.26

For the ANFIS model, different numbers of membership functions (3, 4, 5, 6) and various types of membership functions triangular membership function (trimf), trapezoidal membership function (trapmf), generalized bell membership function (gbellmf), gaussian membership function (gaussmf), pi-shaped membership function (pimf) were tested. The training RMSE values ranged from 0.21 to 0.27, indicating the model's performance during the training phase, while the testing RMSE values ranged from 0.23 to 0.29, reflecting the model's accuracy on unseen data.

The ANFIS model demonstrated significantly lower RMSE values for both training and testing phases compared to the SVM model. This indicates that the ANFIS model had better prediction accuracy and was more effective in handling the complexity of the defect data. The SVM model that showed higher RMSE values, suggesting that its predictions were less accurate compared to the ANFIS model. The variation in RMSE values across different SVM models and cross validation folds highlights the importance of model selection and validation in achieving optimal performance. The ANFIS model outperformed the SVM model in terms of RMSE, making it a more suitable choice for predicting construction defects for this study.

4.2 Model Selection

Based on the model performance result, the ANFIS model consistently outperforms the SVM model in predicting defect. The comparison of RMSE values highlights the importance of model selection in achieving optimal performance. The ANFIS model's lower RMSE values indicate better prediction accuracy, making it a more suitable choice for predicting construction defects. The ability of ANFIS to handle complex data patterns and provide reliable predictions is crucial for proactive construction quality management.

4.3 Data Analysis

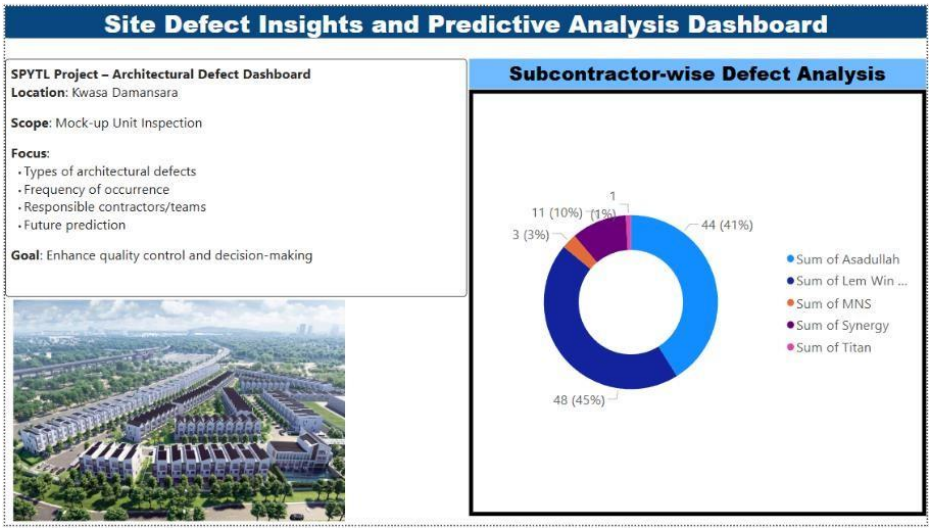
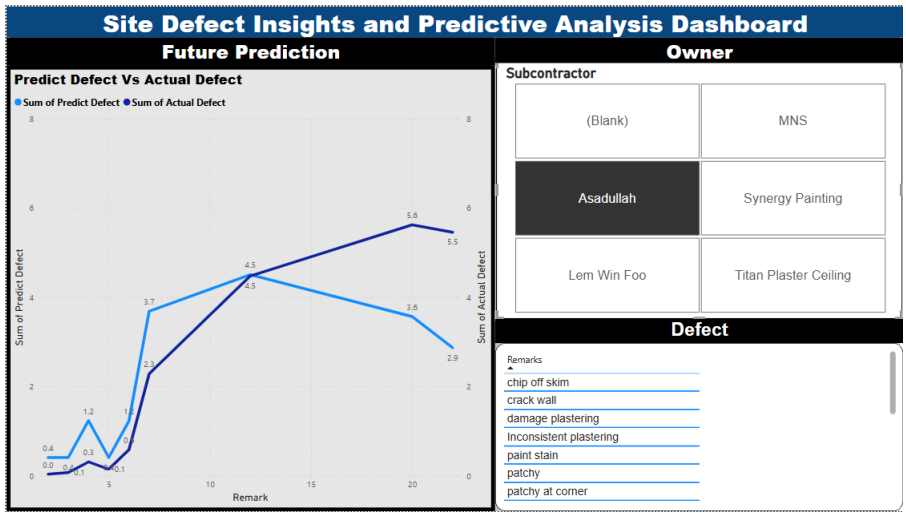


Figure 2: Defect interactive dashboard on power BI

As part of the analyse defect prediction results through an interactive Power BI dashboard that highlighting actual versus predicted defects while identifying recurring quality issues for proactive construction quality management. Figure 2 show that the SPYTL Project at Kwasa Damansara focuses on architectural defects identified during the mock-up unit inspection. The dashboard aims to enhance quality control and decision-making by providing detailed insights into defect types, frequency of occurrence, responsible teams and future predictions.

Figure 3: Dashboard for predict defect vs actual defect and valuable feedback on the



performance of subcontractors listed.

The insights gained from this graph are crucial for improving construction quality. Accurate predictions allow for proactive management of defects, enabling timely interventions to prevent issues before they escalate. By identifying recurring defects and their patterns, construction teams can implement targeted quality control measures to address specific problems.

For example on figure 3, if the graph shows a high number of predicted defects, it indicates a recurring issue that needs immediate attention. Quality management teams can investigate the root causes such as improper installation or material defects and take corrective actions to resolve the problem. This proactive approach helps in maintaining high construction standards and reducing the occurrence of defects.

Furthermore, the graph provides valuable feedback on the performance of subcontractors listed in the Subcontractor and Owner sections. By analyzing defect patterns associated with specific subcontractors, project managers can assess their quality of work and hold them accountable for recurring issues. This information supports better subcontractor management and ensures that quality standards are consistently met across the project.

5.0 CONCLUSION

This research successfully identified defect data and developed machine learning models, specifically ANFIS and SVM to predict construction defects based on actual site data. Through data pre-processing and training, both models were evaluated to determine the best fit for accurately predicting defects. The ANFIS model consistently outperformed the SVM model based on the RMSE value metric that making it more suitable for predicting defects on-site.

Additionally, the study focused on an architectural defect dashboard using Power BI as our data processing and visualization tool. Power BI facilitated the connection of data sources and achieved effective data visualization, making it convenient to share within the project team and significantly accelerating communication. This analysis is particularly useful for sites with similar construction defects. Future studies can explore additional machine learning models and use Power BI as an analysis tool to easily visualize data. Furthermore, future research can delve deeper into defect prediction and compare the performance with other subcontractors based on on-site defects.

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Predicting Pile Set Criteria Using Machine Learning: A Data-Driven Approach

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ABSTRACT

This study presents a machine learning-based approach to predicting pile set criteria in geotechnical engineering, addressing the limitations of traditional empirical methods. Accurate pile set prediction is essential for ensuring the structural performance and safety of deep foundations. Conventional practices often rely on field judgment and formulas that may lack precision and adaptability. In this research, historical piling records including blow count, depth of piles, hammer specifications, settlement, and temporary compression were used to train and compare three predictive models: Adaptive Neuro-Fuzzy Inference System (ANFIS), Regression Learner Fine Tree, and Support Vector Machine (SVM). This study involved RC square Piles (200 mm × 200 mm) driven using 2.5-3.5-ton hydraulic hammer at a site with two distinct soil layers: the first layer is cohesive soil composed of firm silt and clay while, the second layer comprises medium-dense sand and gravel, which is non-cohesive. Model performance was assessed using Mean Squared Logarithmic Error (MSLE). Results showed that ANFIS outperformed both Fine Tree and SVM models in prediction accuracy. This approach demonstrates the potential of machine learning to enhance prediction reliability in foundation engineering, especially for projects with similar soil profiles. The methodology can be adapted and extended to other geotechnical conditions with proper calibration.

Keywords: Machine Learning, Pile Set Criteria, ANFIS, SVM, Predictive Modelling.

1.0 INTRODUCTION

The construction industry continues to evolve, with growing demand for greater accuracy and efficiency in foundation engineering. In pile foundation systems, determining whether a pile has reached the required set criteria is critical to ensuring structural integrity. Traditionally, pile set is assessed through empirical formulas and field judgment, which can be time-consuming, error-prone, and highly dependent on-site expertise (Phan & Chu, 2019; Liew et al., 2017).

Machine learning (ML) offers a promising alternative by leveraging historical data to automate and enhance decision-making in geotechnical applications. Previous studies have shown the effectiveness of ML in predicting pile capacity and penetration resistance (Zhang et al., 2020; Shahin, 2020), as well as settlement and compression behaviours (Juang et al., 2018). These approaches address the limitations of conventional methods by modelling non-linear patterns and incorporating complex input variables such as soil type, pile geometry, and driving energy.

Despite the growth of ML in geotechnical research, limited studies have focused specifically on predicting pile set criteria. This study aims to fill that gap by developing and comparing three ML models, ANFIS, Regression Learner Fine Tree, and Support Vector Machine (SVM), to predict two key components: settlement and temporary compression. These values are then used to compute the pile set criteria. The case study focuses on reinforced concrete square piles (200 mm × 200 mm) installed using 2.5- and 3-ton hydraulic hammers at a site characterized by two distinct soil layers: the first being cohesive soil composed of firm silt and clay, and the

second comprising medium-dense sand and gravel. Historical piling data, including blow count, penetration depth, settlement, and temporary compression, were used to develop a dataset for model training and validation.

Accordingly, this study aims to identify the most accurate machine learning model for predicting pile set criteria by comparing ANFIS, Regression Learner Fine Tree, and SVM. The selected model is then implemented into a MATLAB-based prediction system to support field application. Finally, the system's performance is validated to assess its reliability in estimating pile set outcomes using site-specific data. The study contributes to improving pile assessment accuracy while reducing reliance on manual methods, offering a more efficient and objective decision-making framework for foundation engineering.

2.0 METHODOLOGY

This research adopts a systematic methodology to develop, evaluate, and deploy machine learning models for predicting pile set criteria, structured into three phases. Phase 1, Data Collection and Model Development, involves gathering historical piling data and developing machine learning models, including ANFIS, SVM, and Linear Regression Fine Tree. Phase 2, Model Optimization and Selection, focuses on hyperparameter tuning and testing to optimize performance using RMSE, followed by model comparison and selection based on MSLE. Phase 3, Predictive Application Development and Validating, involves creating a MATLAB-based predictive application, integrating the best-performing model, and validate its accuracy and usability for practical implementation. These phases are illustrated in Figure 1.

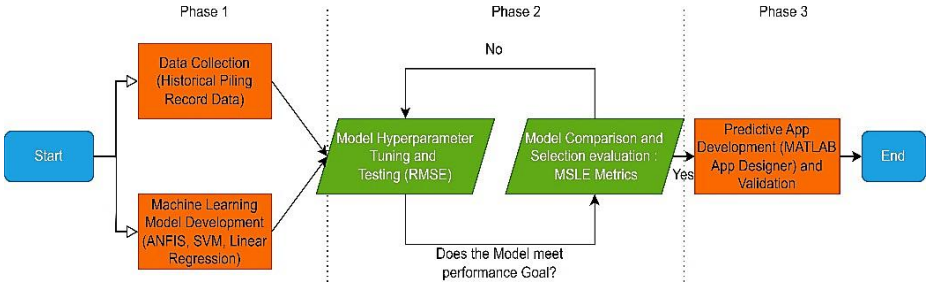

Figure 1 Methodology Flow Chart

2.1 Data Collection Approach

The dataset for this study was sourced from historical piling records at an active construction site. It includes key parameters such as penetration depth, blow count, settlement, and temporary compression, which are recognized indicators of pile behaviour in geotechnical engineering (Juang et al., 2018). Additional site-specific information, such as soil classification and hammer specifications, was gathered from geotechnical reports and piling documentation.

To prepare the data for machine learning, outliers were removed to prevent distortion, and numerical variables were normalized to ensure consistent scaling. This step is especially important for models sensitive to input magnitudes, such as Support Vector Machines (Goodfellow et al., 2016). The dataset was then split into 80 percent for training and 20 percent for testing, following standard machine learning practices (James et al., 2017).

Model-specific pre-processing was also applied. For ANFIS, categorical encoding was used for repeated inputs such as hammer weight (2.5 or 3 tons), drop height (250 or 300 mm), and fixed blow count (10 blows). These values were numerically encoded to support fuzzy

inference. In contrast, the Fine Tree and SVM models only required outlier removal and normalization, as they handle structured numerical data with minimal transformation. The full list of input variables is shown in Table 1.

Table 1 Historical Piling Record Data Variables Used

Variables	Type	Unit	Description
Final Penetration Depth	Input	m	Depth at which pile driving is completed
Blow Count	Input	~	Number of blows required at the final depth
Hammer Drop Height	Input	mm	Height from which the hammer is dropped
Hammer Weight	Input	Ton	Weight pile rig hammer
Set Criteria Blow Count	Input	~	Blow count for Pile Set criteria Taking
Settlement	Output	mm	Permanent downward displacement
Temporary Compression	Output	mm	Compression during driving
Set Criteria	Output	~	Indicator if pile has reached sufficient stability

2.2 Model Development and Evaluation

Three machine learning models were developed and evaluated: Adaptive Neuro-Fuzzy Inference System (ANFIS), Support Vector Machine (SVM), and linear regression Fine Tree. ANFIS combines neural networks and fuzzy logic to capture complex non-linear relationships, making it well-suited for geotechnical applications. SVM, implemented with a radial basis function (RBF) kernel, was selected for its ability to handle high-dimensional datasets. Fine Tree served as a baseline model to benchmark the performance of the more advanced algorithms (Alavi & Gandomi, 2017).

Hyperparameter tuning was conducted using grid search. For ANFIS, membership functions and learning rates were optimized, while for SVM, the regularization and kernel coefficients were adjusted. Root Mean Squared Error (RMSE) was used during tuning to measure model sensitivity to large prediction errors and identify optimal configurations (Phan & Chu, 2019). RMSE values were calculated automatically during training and guided the tuning process.

To compare the predictive performance of the models, Mean Squared Logarithmic Error (MSLE) was used. MSLE measures the squared difference between the logarithms of actual and predicted values, placing greater penalty on underpredictions. This is critical in geotechnical applications, where conservative predictions are essential for safety (Rezan Bakir et al., 2024). The MSLE formula is:

$$\text{MSLE}=\frac{1}{n}\sum_{t=1}^{n}(log(1+At)-\log(1+Ft))^2 \qquad (1)$$

Here, log (1+*At*) log (1+*At*) and log (1+*Ft*) log (1+*Ft*) represent the natural logarithms of the actual and forecasted values, respectively. By combining RMSE for model tuning with MSLE for comparative analysis, this study ensures a thorough evaluation of model accuracy and suitability for practical geotechnical engineering use (Zhang et al., 2020).

2.3 Data Analysis Method

Data analysis began with exploratory data analysis using scatter plots to identify patterns, trends, and relationships among key variables in the dataset. This step helped reveal underlying structures and informed the selection of relevant features for modelling. Three machine learning models, Adaptive Neuro-Fuzzy Inference System (ANFIS), Regression Learner Fine Tree, and Support Vector Machine (SVM), were then trained using ten important features known to affect pile behaviour (Juang et al., 2018). The models' performance was assessed using Mean Squared Logarithmic Error (MSLE), a metric that accounts for both accuracy and scale sensitivity, enabling a robust comparison to determine the most effective model for predicting pile set criteria (Hyndman & Koehler, 2006).

3.0 RESULT AND ANALYSIS

3.1 Hyperparameter Tuning Results

Hyperparameter tuning was performed for the ANFIS, Fine Tree, and Support Vector Machine (SVM) models to optimize prediction accuracy. For ANFIS, the best settlement predictions were achieved using the generalized bell-shaped membership function with a 5555-rule structure, while temporary compression was best predicted using the Gaussian membership function with the same rules. This highlights the model's sensitivity to membership function selection in capturing complex soil–pile interactions.

5

The Fine Tree model performed optimally with 5-fold cross-validation and a leaf size of 8 for settlement, and 25-fold cross-validation with a leaf size of 6 for temporary compression. The SVM model achieved the best results using a quadratic kernel, with default cross-validation for settlement and 25-fold cross-validation for temporary compression. These findings emphasize how kernel choice and cross-validation strategies significantly impact model performance.

3.2 Model Performance Comparative Analysis Using MSLE Metric

The ANFIS model consistently produces the lowest MSLE values for settlement prediction, mostly staying below 0.05 during training and testing. The Fine Tree model also performs reasonably well, with MSLE generally under 0.1 but slightly more scattered. In contrast, the SVM model shows greater variability, with several test points exceeding 0.3 and one outlier above 0.45. Since MSLE penalizes underestimations more than overestimations, high MSLE values indicate significant underprediction, which may underestimate critical settlement values in engineering practice. Figure 2 illustrates these MSLE performances across the three models.

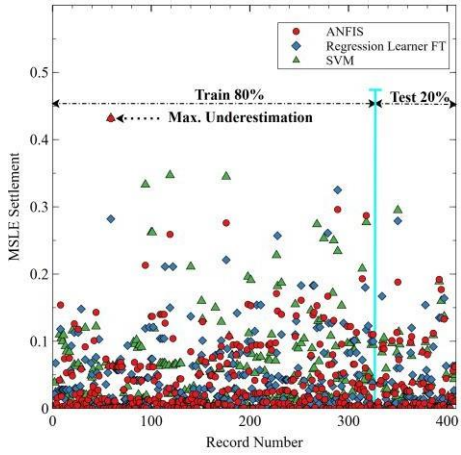

Figure 2 MSLE Settlement Prediction

The ANFIS model also demonstrates the best consistency in predicting temporary compression, with most MSLE values below 0.03 and only a few exceeding 0.1. The Fine Tree model shows moderate MSLE values, generally under 0.15, though a few spikes approach 0.25. The SVM model again performs relatively poorly, with several data points above 0.2 and at least one exceeding 0.35, indicating repeated underestimation. This highlights the importance of choosing models that minimize MSLE, particularly in applications where underprediction can lead to unsafe or overly conservative engineering decisions. Figure 3 presents the MSLE distribution for temporary compression prediction across the three models.

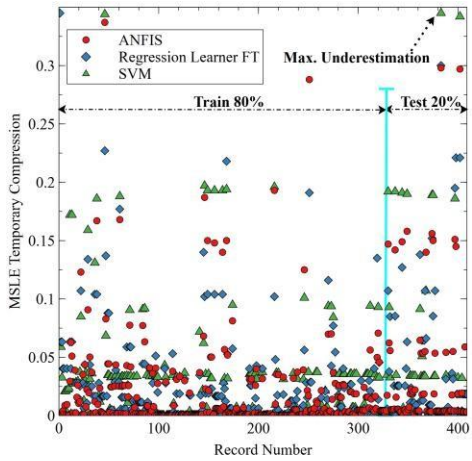

Figure 3 MSLE Temporary Compression Prediction

In conclusion, MSLE analysis reveals that the ANFIS model consistently outperforms the other models by producing the lowest and most stable error values across both settlement and temporary compression predictions. Its superior performance is particularly significant given MSLE's sensitivity to underestimation, confirming ANFIS's strength in delivering predictions that avoid critical underprediction biases observed in the SVM model.

3.3 App Development and Validation

Based on the comparative analysis, the ANFIS model consistently outperformed the Fine Tree and SVM models in predicting both settlement and temporary compression. Its superior MSLE performance indicated lower prediction errors and greater robustness under varying input conditions. These findings support the use of ANFIS as the core model in tools aimed at evaluating pile set criteria in practical engineering contexts.

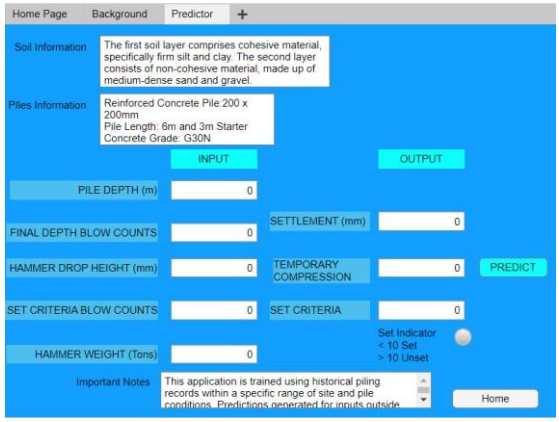

Figure 4 Prediction Tab of Developed Prediction App

To operationalize the model, a MATLAB-based application was developed using App Designer for practical use in both field and design settings. The application includes three main tabs, with the Prediction Page serving as the core interface. It presents essential site information, such as soil type and pile specifications, to help users contextualize predictions and ensure the input conditions align with those used during model development. The interface accepts user input and displays predicted settlement, temporary compression, and the computed pile set criteria. A visual indicator provides quick interpretation: green signifies the pile is set (value ≤ 10), while red indicates it is unset (value > 10). The interface design is shown in Figure 4.

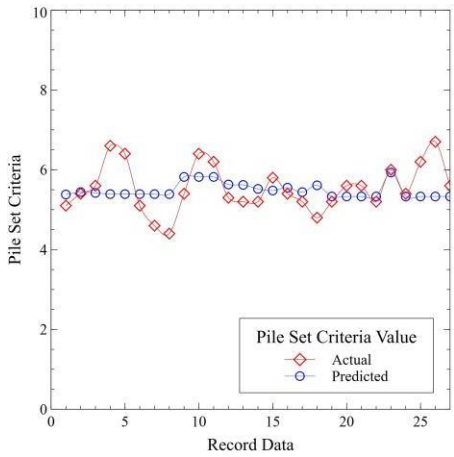

Figure 5 Pile Set Validation Result

Validation was performed on 27 unseen data points, comparing predicted pile set values from the ANFIS model against actual field measurements. The predictions closely aligned with

observed trends, with only minor deviations in high-variability cases. These results confirm the model's reliability when applied to new data and support its suitability for deployment in projects with similar geotechnical conditions. The validation results are illustrated in Figure 5.

4.0 CONCLUSION

This research successfully demonstrated the application of machine learning techniques, specifically Adaptive Neuro-Fuzzy Inference System (ANFIS), Support Vector Machine (SVM), and Fine Tree, for predicting pile set criteria using actual site data. The study focused on RC square piles (200 mm × 200 mm) installed using 2.5- to 3.5-ton hydraulic hammers under controlled conditions, with key parameters such as final pile penetration depth, blow counts, hammer weight, hammer drop height, settlement, and temporary compression selected based on their field relevance and historical significance. Following data pre-processing and training, each model was evaluated to determine the most effective approach for predicting pile set values.

Comparative analysis based on Mean Squared Logarithmic Error (MSLE) revealed that the ANFIS model provided superior predictive accuracy. Its integration of fuzzy logic with adaptive learning enabled it to effectively capture complex nonlinear relationships and soil, pile interactions. To operationalize this model, a MATLAB-based application was developed, enabling users to input site parameters and obtain predictions in a user-friendly interface. To verify the model's performance beyond the training dataset, validation was conducted using 27 unseen data points. The results demonstrated that ANFIS maintained strong predictive consistency, with predicted pile set values closely matching actual site measurements.

This confirms the model's generalization capability and supports its suitability for real-world deployment in projects involving similar soil conditions, particularly cohesive top layers of firm silt and clay as found in this study. While the current model is tailored to specific conditions, the methodology is scalable and can be adapted to broader applications with further calibration. Future research may consider incorporating real-time field data, additional machine learning models, and diverse geotechnical conditions to further enhance the robustness and applicability of pile set prediction systems.

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Prediction Of Compressive Strength Of Concrete With Ceramic Replaced As Fine Aggregates For Sustainable Construction

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ABSTRACT

Nowadays, the demand for sustainable construction practices has increased and has driven the exploration of other alternative materials to reduce degradation and resource depletion in the future. This research investigates the prediction of the optimum percentages of ceramic waste as a replacement for fine aggregates in concrete production and to encourage resource efficiency and waste valorization. The objective is to identify the potential for unconventional recycled materials to improve concrete properties. Prediction of recycled material-based concrete performance models using Support Vector Machine (SVM) and Gaussian Process Regression (GPR) to effectively model the behaviour of concrete mixtures incorporating ceramic waste. Besides that, to compare the performance of recycled material-based concrete with standard concrete mixtures. The percentages of replacement ceramic waste in concrete mix are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%. The result showed that the optimum percentage of replacement ceramic waste in concrete mix is 10%. The statistical performance indicators consist of Root Mean Square Error (RMSE), Coefficient of Determination (R^2), Mean Absolute Error (MAE), and Mean Squared Error (MSE) and the output will be extracted from the chosen artificial intelligence (AI) model, which is Support Vector Machine (SVM) and Gaussian Process Regression (GPR). This study concludes that the SVM model demonstrated high accuracy of predictive performance by achieving an R-squared (R^2) value of 1.00, which indicates an optimal design prediction. Ceramic waste has significant potential as an eco-friendly alternative for fine aggregate replacement.

Keywords: Ceramic waste, Compressive strength, Support Vector Machine (SVM), Gaussian Process Regression (GPR)

1.0 INTRODUCTION

The construction industry is one of the largest consumers of natural resources globally in the world (Nizam & Abdullah, 2021). Concrete is among the most common construction materials used in construction because it is durable, cost-effective, and versatile for different uses, from roads, buildings, bridges, and water retaining structures to development. However, the increasing demand for concrete has led to a simultaneous increase in the extraction of natural aggregates, particularly fine aggregates such as river sand. The environmental problems of concrete are also due to the excessive consumption of natural aggregates for concrete construction (Bakar & Rahmat, 2020). The continuous accumulation of solid waste in landfills has led to increased strain on landfill capacity (Zahraa Jwaida, 2024). Thereby heightening the risk of environmental contamination due to the potential leaching of hazardous compounds into adjacent soil and groundwater systems (Singh, 2018). These products are often simply discarded in landfills, where they create long-term ecological hazards by occupying space and contaminating soil and water with harmful chemicals. Therefore, the way to manage the issue represents a major global challenge, which is further exacerbated by the resistance and the non biodegradability of ceramic waste. The rising consumption of natural aggregates and the large volume of ceramic waste need to give attention to an innovative and sustainable solution (EL

HAWARY & Elnemr, 2020). Adopting circular economic strategies offers a practical approach to addressing these challenges while enhancing resource sustainability and environmental protection.

This research intends that ceramic waste as an underutilized material based on modern industry progress is a thoughtful alternative to fine aggregates. Utilization of ceramic waste as a part of concrete not only allows for recycling of industrial residues and waste diversion from dumping but also reduces dependency on finite natural resources, thereby promoting conservation. As a replacement material, waste ceramic can be used to enhance the mechanical properties of concrete and help bring both environmental and economic benefits. The objectives of this study are three-fold: firstly, to identify the potential use of non-conventional waste materials, namely ceramic waste, in improving the physical and mechanical strength of concrete; secondly, to develop a predictive model using Support Vector Machine (SVM) and Gaussion Process Regression (GPR) to forecast the performance of recycled material-based concrete; and thirdly, to compare the performance of ceramic concrete with conventional concrete mixtures. Further, this approach has also been aligned with global initiatives in efforts to achieve the SDGs, especially concerning responsible consumption and production.

2.0 METHODOLOGY

In this section of the methodology, the research framework is structured into three phases as illustrated in the flowchart in Figure 1. Starting phase 1, the research begins with identifying the problem which focuses on the overuse of natural sources such as fine aggregates in concrete mixture and the need for sustainable alternatives to decrease the degradation of waste. Followed by a comprehensive literature review to research the existing studies related to the recycled materials in concrete, particularly ceramic waste and to establish a strong theoretical foundation. In this study, ceramic waste was selected as a replacement material in the concrete mixture to evaluate the performance in terms of compressive strength and sustainability. The properties of ceramic waste, such as specific gravity, water absorption and fineness modulus were determined by the standards of properties of ceramic waste. All these characteristics are crucial to evaluating the materials suitability for use in the concrete mix. Then, appropriate materials are selected for the study based on their suitability.

In phase 2, data was collected regarding the existing data and by using the existing formula for the compressive of strength of the concrete mixtures. This was also followed by the development of a mixed design incorporating ceramic waste as a replacement for fine aggregates. In mix design development, the method of analysis is by using the software MATLAB. In MATLAB software, the model that is used in this study is the model SVM, which includes Linear SVM, Quadratic SVM, Cubic SVM, and SVM Kernel. For GPR is Rational Quadratic, Squared Exponential, Matern 5/2, and Exponential. A test run is conducted to evaluate the optimum percentages that are effective to replace the fine aggregates in the concrete mix. If the result is unsatisfactory, the process will loop back to revise the mixed design.

When the result is satisfactory, the result will continue with analysis to the conclusion based on the performance of the ceramic as a replacement for fine aggregates. The study's findings support the use of recycled materials and sustainable construction approaches.

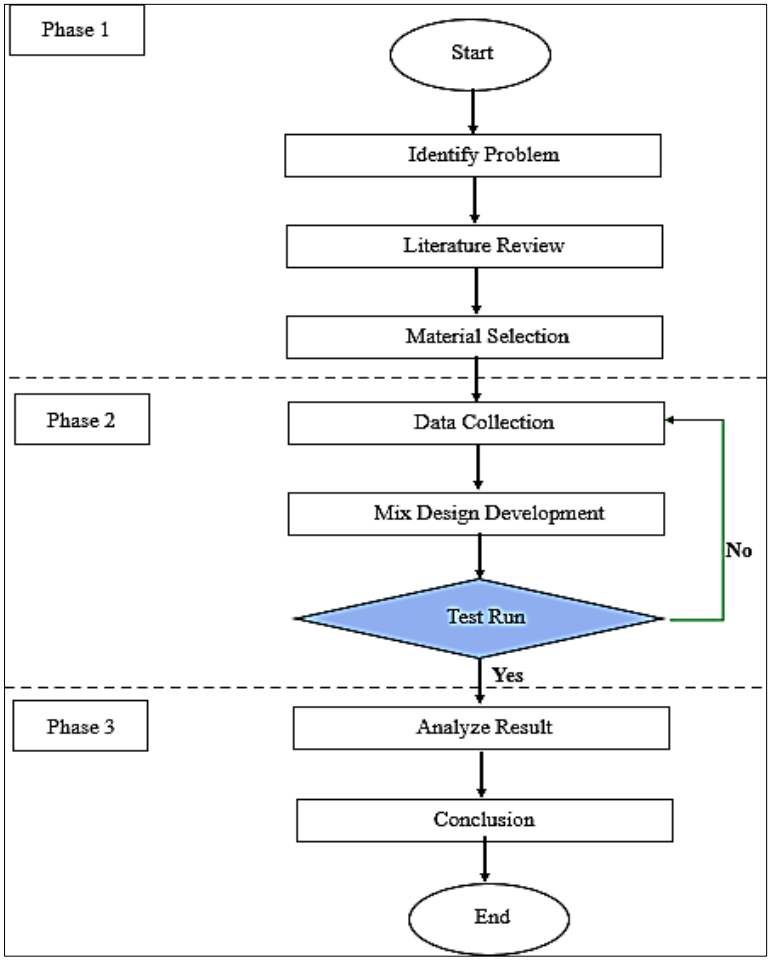


Figure 1 Flowchart for Research Framework.

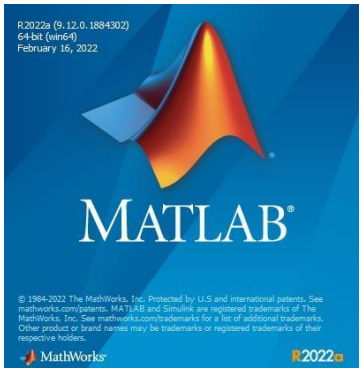
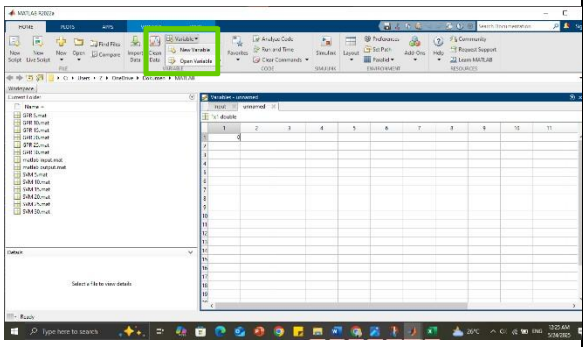
2.1 Procedure for Prediction by using Model SVM and GPR in MATLAB software

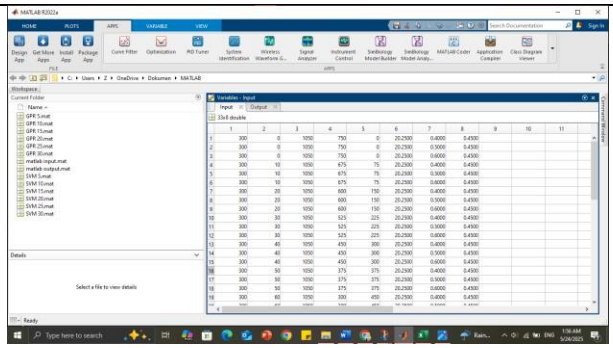
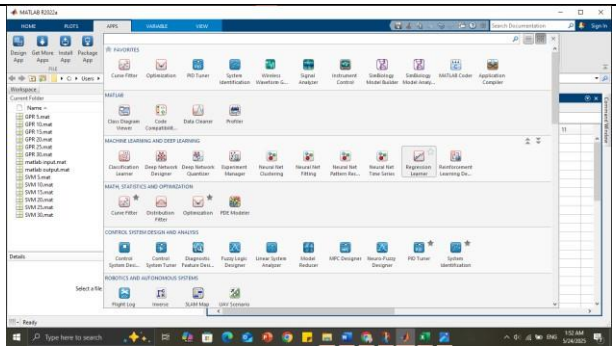
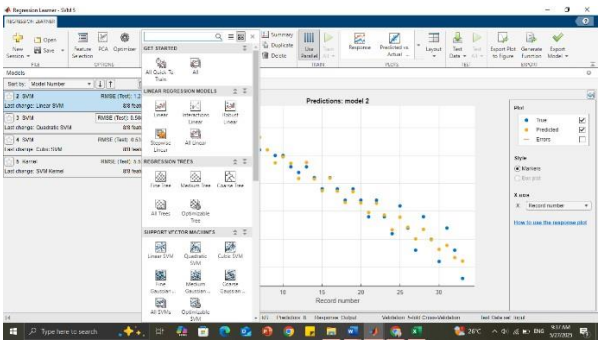
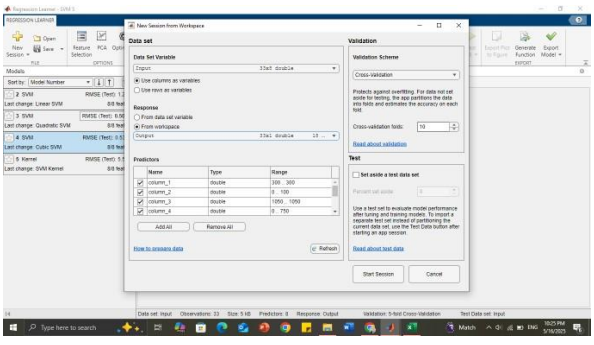
In this section, the procedure of prediction will be explained. To create and process data in MATLAB by applying machine learning, one can proceed similarly to other types of data. First, open MATLAB and go to the workspace button. Select the variable section and click to create a new variable, and next import your input predictor and output response data from outside sources like Excel, CSV, or MAT files. After the successful import of data, navigate to the toolbar and click on the "Apps" tab. From the list of available programs, select "Regression Learner" for training and testing machine learning models.

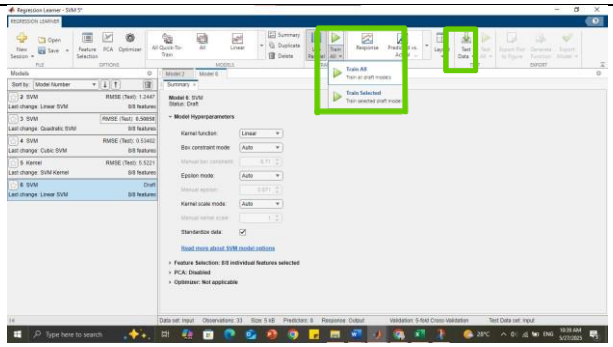
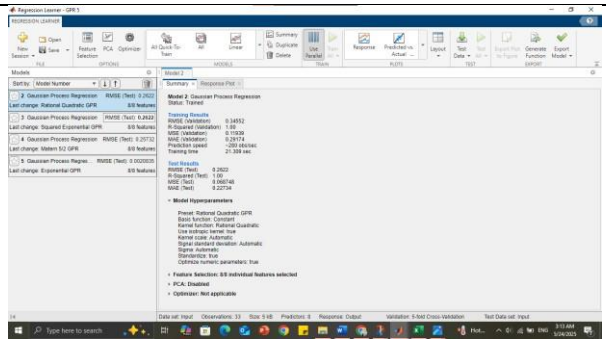
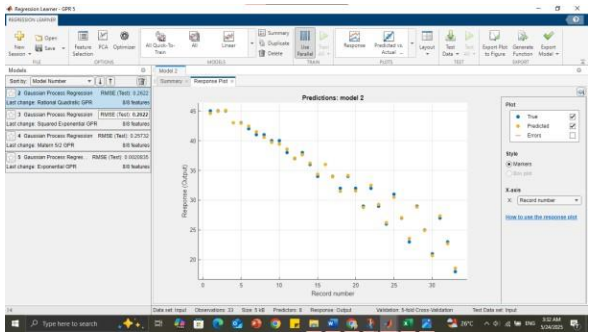
Within the Regression Learner window, select the corresponding machine learning models. For Support Vector Machine (SVM), Linear SVM, Quadratic SVM, Cubic SVM, and Kernel SVM can be employed. For Gaussian Process Regression (GPR), some suggested models are Rational Quadratic, Squared Exponential, Matern 5/2, and Exponential. Having chosen the preferred models, identify the data by indicating the input features, predictors and the target variable response. Set the cross-validation setting and go up starting from 5-fold cross-validation until 30-fold cross-validation to make sure that the model validation is thorough.

Once the setup is complete, click the “Train” button to begin the training process for all selected models. When the training is complete, if any isolated test dataset is present, choose it and press the "Test All" button to test how well the models perform on new data. After completing the training and testing al the data set the MATLAB will provide an overview of the performance such as Root Mean Square Error (RMSE), R-Squared (R^2), Mean Squared Error (MSE), and Mean Absolute Error (MAE). Additionally, the response plot will provide a graphical representation comparing the predicted values against the actual data, helping to visually assess the accuracy of each model.

Table 1 Procedure for Prediction by using Model SVM and GPR in MATLAB Software

STEP	EXPLANATION
	Open MATLAB to apply machine learning algorithm using Support Vector Machine (SVM) and Gaussian Process Regression (GPR).
	Click on the variable and choose “new variable”.

	Insert the input and output data from files.
	Next, click on the “apps” button and choose “regression learner”.
	Next, select the SVM and GPR models to be used. SVM: Linear SVM, Quadratic SVM, Cubic SVM & SVM kernel. GPR: Rational Quadratic, Squared Exponential, Matern 5/2 & Exponential
	Select for data set variable (input) and the response (output). Set the cross-validation folds, starting from 5 to 30.

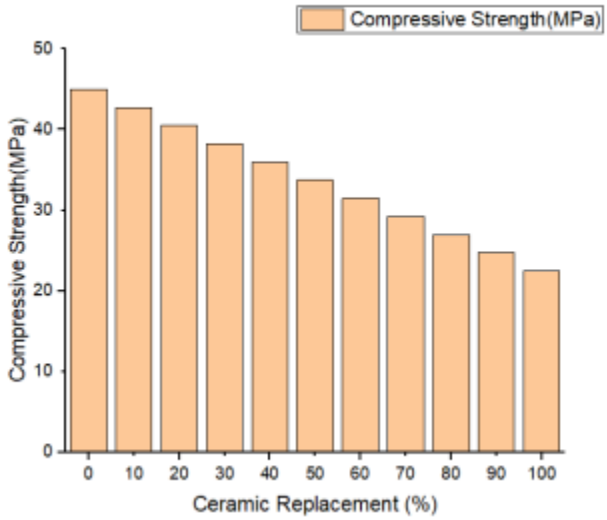
	After selecting all algorithm models, click the 'Train' button to initiate training for all models. Once training is complete, select the test dataset and click 'Test All' to evaluate their performance.
	After completing all training and testing, the summary of RMSE, R^2, MSE, and MAE results will be displayed as shown in the image.
	The response plot will display the graph of the predicted values.

3.0 RESULT AND DISCUSSION

After creating various data-driven models, the validation test of the dataset was conducted to identify the ability of the model network. Four statistical indices are chosen to assess the predictive accuracy of the model network which are Root mean square error (RSME), R Squared (R^2), Mean absolute error (MAE) and mean square error (MSE). Regression Learner's apps are used to generate the model network. Support Vector Machine (SVM) and Gaussian Process Regression (GPR) were chosen to identify the model accuracy by changing the cross-validation fold and model. Other parameters were kept constant to achieve the optimal training rule.

In this study, ceramic waste was used to replace the fine aggregates in concrete mix at variances of percentages ranging from 10% to 100%, to assess the effect on compressive strength. The specific range has been chosen to better understand how gradual increments of ceramic composition influence the mechanical behaviour of the concrete. The previous study, commonly

used interval percentages of ceramic waste like 20%, 40% and 60%, but in these increments may overlook the significant changes in strength behavior that occur between the points. By using 10% intervals, this study aims to capture a more precise trend and transition point where performance begins to significantly weaken.



Graph 1 - Ceramic replacement (%) VS Compressive Strength (MPa)

For example, based on the result shown in Graph 1, the compressive strength of the concrete mix decreases as the percentage of ceramic waste replacement increases. The graph shows at 0% of replacement represents the conventional concrete mix with a compressive strength show approximately 47 MPa. At 10% of replacement, the strength of concrete slightly drops to around 44 MPa and at 50% of replacement, the compressive strength drops below 35 MPa. The lowest compressive strength is obviously at 100% replacement of ceramic which drops to 22 MPa.

Therefore, the reason to 10% to 100% replacement range with reduced intervals has been chosen is to understand more clearly the limit of ceramic waste usability in concrete without affecting the structure. This not only provides valuable information on optimizing mixes but also assists in developing practical guidelines for sustainable material replacement in construction.

Table 2 The best model between SVM and GPR

	RSME		R-Squared		MSE		MAE	
	Training	Test	Training	Test	Training	Test	Training	Test
SVM	0.55941	0.50858	0.99	1.00	0.31293	0.25866	0.44958	0.41659
GPR	0.33	0.00208635	1.00	1.00	0.1089	4.34E-06	0.29098	0.0014969

Table 2 presents a comparison of the performance model between model Support Vector Machine (SVM) and the Gaussian Process Regression (GPR). Each model was evaluated with the same key metrics such as Root Mean Square Error (RMSE), R-Squared (R^2), Mean Squared Error (MSE), and Mean Absolute Error (MAE) and each for both training and testing datasets.

In the SVM model, both the training and test sets have R^2 values of 0.99 and 1.00, respectively, indicating high correlation between predicted and actual compressive strength values. However, at the time of testing, RMSE and MAE are 0.5088 and 0.41659, respectively, and are relatively higher, indicating a moderate level of prediction error. Further, the MSE during testing is 0.25866, indicating high deviation in terms of squared errors.

In contrast, the GPR model performs much better than SVM in all measures. R^2 is 1.00 for both training and test, which reflects a perfect prediction fit. More significantly, test RMSE and MAE values are very low at 0.00208635 and 0.0014969, respectively, reflecting negligible prediction error. The value of MSE at 4.34E-06 also reinforces the high precision of the GPR model.

Based on comparative analysis, the Gaussian Process Regression (GPR) model is more appropriate than the Support Vector Machine (SVM) model in the prediction of the compressive strength of concrete with ceramic waste as fine aggregates. The GPR model achieved near perfect accuracy with a negligible margin of error and hence is a better approach for the prediction of concrete performance under this condition. Therefore, the GPR model is proposed to be the most superior machine learning method for future predictive modeling in green concrete research.

4.0 CONCLUSION

This study demonstrates that ceramic waste can be effectively used as a fine aggregate replacement in concrete. It shows that a 10% replacement of ceramic in the concrete can achieve improved strength and support the case for its use in sustainable construction practices. This improvement in mechanical behaviour reflects the potential of ceramic waste as a viable and sustainable substitute material in building construction. Its use contributes to reducing the use of natural resources and assists in mitigating environmental issues related to ceramic waste dumping, which aligns well with the agendas of sustainable construction and circular economy concepts. In addition, this study incorporates machine learning models, such as Support Vector Machine (SVM) and Gaussian Process Regression (GPR) to predict the response of modification of concrete mix, which replaces the fine aggregates with various percentages of ceramic waste. Based on the analysis, the best model and most accurate for predicting the compression strength of concrete is Gaussian Process Regression (GPR). This research contributes meaningful insight into the feasibility of ceramic waste as a construction material, encouraging future studies to explore its long-term durability, behaviour under various environmental conditions, and performance in combination with other recycled materials.

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PROSPECT: Mobile-Driven Enhancement of Structural Assessment and QA/QC Processes

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ABSTRACT

Quality Assurance and Quality Control (QAQC) practices in construction are essential to ensure that all the work complies with project specifications and regulatory standards throughout on-site execution. The problem occurs during the assessment of structural trade by relying on traditional methods. This traditional method of data collection using paper-based checklist provides challenges due to the need for numerous copies and re-entering the data manually in Excel. This study aims to develop mobile application named PROSPECT for structural assessment process to improve efficiency, accuracy, and environmental sustainability. A paired sample t-test revealed statistically significant improvements ($p < 0.001$) in usability, data entry, output quality, and sustainability, affirming the practical relevance of the application. The overall evaluation demonstrated a marked enhancement, with the average mean score escalating from 2.50 in the pre-development phase to 4.52 post-implementation, signifying a substantial advancement in critical dimensions such as usability, data handling efficiency, and sustainable practice integration. Among the assessed criteria, the most significant improvements were observed in usability and output quality, with exceptionally high t-values of 61.00, indicating that the developed application is highly user-friendly and capable of generating structured, reliable reports that enhance documentation quality on-site.

Keywords: digitalization, quality assurance, paperless, mobile application development.

1.0 INTRODUCTION

The construction industry in Malaysia continues to serve as a vital contributor to national development, yet it remains burdened by persistent issues in maintaining effective quality assurance, particularly within inspection workflows. One of the primary challenges lies in the continued reliance on paper-based checklists, as observed in the OSK Group's Quality Standard (OQS) Assessment. Although the OQS framework is conducted bi-monthly and plays a crucial role in ensuring compliance with Quality, Safety, Health, and Environmental (QSHE) requirements, its manual nature results in operational inefficiencies. These include difficulties in data management, susceptibility to human error, and delays in report processing, all of which diminish the effectiveness of quality monitoring.

The aim of this project is to develop an application for OSK Quality Standard (OQS) Structural Assessment. The purpose is to solve the current practice that is currently using paper-based checklists in order to reduce the usage of paper and to save time.

1. To identify problems and solutions in the industry.
2. To develop an application for Structural Quality Assessment in compliance with CIDB CIS7:2014 (PROSPECT).
3. To evaluate the effectiveness of the developed PROSPECT application.

by assessing its impact on usability, accuracy, efficiency, and sustainability through feedback from actual users in the field.

The scope of this study is restricted to structural inspections within the OSK Group's Residensi Nuria @ Taman Melawati project, under the oversight of the QSHE Department. The digital tool was tested on-site and evaluated through feedback collected from various construction personnel, including QAQC engineers, QAQC inspectors, project engineers, and site engineers. While the study does not extend to departments unrelated to structural assessment or to external organizations, it encompasses both quality control and site management perspectives, ensuring that the application is assessed from operational and compliance standpoints.

2.0 METHODOLOGY

The methodology adopted in this study is structured into three main phases: problem identification, application development, and effectiveness evaluation. As illustrated in Figure 1, the workflow began with defining the problem and reviewing regulatory standards, proceeded through digital solution development, and concluded with evaluation and recommendations based on field performance data.

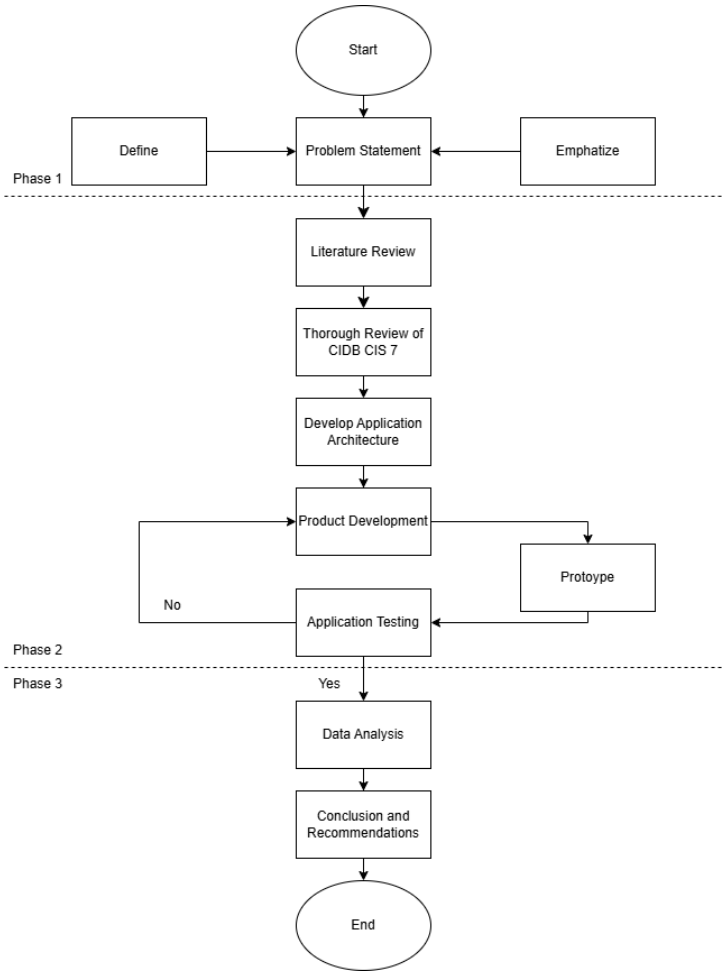

Figure 1: Methodology Workflow for Digitalizing the OQS Assessment Process

As shown in Figure 1, the first phase identifies key inefficiencies in the current paper-based assessment practices that were identified through literature review and an in-depth analysis of CIDB CIS 7:2014 to ensure compliance with national standards. This phase also involved consultations with site-based QAQC personnel to better understand the operational gaps.

The second phase focused on the development of the PROSPECT application. This involved designing a mobile interface tailored for structural quality assessment, incorporating essential features such as dynamic checklists, automatic scoring, and report generation. The development process utilized Flutter as the primary framework due to its cross-platform capabilities, while Firebase provided real-time database support and secure authentication. Android Studio facilitated iterative testing through emulator environments, and the integration of the Flutter PDF package enabled the generation of structured, standards-compliant reports.

The final phase involved real-world testing and evaluation of the application at the Residensi Nuria @ Taman Melawati site. The application was assessed by QAQC engineers, QAQC inspectors, site engineers, and project engineers, using structured questionnaires and paired sample t-tests to measure its effectiveness in comparison to manual practices. The main user interface of the PROSPECT application is shown in Figure 2.

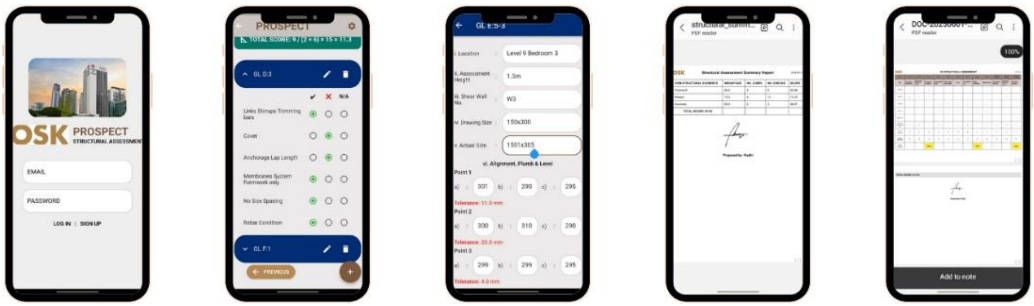

Figure 2: Main interface of the PROSPECT application

Figure 2 illustrates the main interface of the PROSPECT mobile application, designed to facilitate digital structural quality assessments in compliance with the OSK Quality Standard (OQS) and CIDB CIS 7:2014. The first screen displays the login interface, where authorized personnel may securely access the platform using role-based credentials. The second interface represents the checklist module for reinforcement inspection, enabling on-site QAQC personnel to score elements based on real-time conditions. The third screen demonstrates the finished concrete checklist, where data input is used to evaluate parameters such as wall evenness against project-specific tolerances. The fourth screen shows the automatically generated summary report for primary structural trades formwork, reinforcement, and finished concrete formatted with standardized tables, project identifiers, and digital signatures for verification. The fifth screen consolidates assessment data for all sub-trades under each main category, providing a comprehensive view of compliance across structural elements. These interfaces collectively enhance usability, streamline documentation, and reinforce procedural standardization throughout the quality assessment workflow.

3.0 RESULTS AND DISCUSSION

3.1 Problem Identification

To address the first objective of this study, a preliminary survey was conducted involving QAQC engineers, inspectors, project engineers, and site engineers from the Residensi Nuria project. The aim was to evaluate current limitations in the manual OSK Quality Standard (OQS) Assessment workflow

Table 1: Problem Identification of Current OQS Assessment

No.	Problem	Response	
		Yes	No
1.	Transferring data from paper to Excel takes extra time and effort.	100%	0%
2.	The use of printed checklists leads to excessive paper usage on site.	100%	0%
3.	I occasionally experience difficulty keeping track of checklists or notes written during site inspections.	100%	0%
4.	I sometimes need to clarify or confirm past entries with colleagues due to the absence of centralized digital records.	80%	20%
5.	I am open to utilizing a digital platform (e.g., mobile or tablet-based application) to enhance the efficiency and accessibility of OQS Assessment.	100%	0%

As shown in Table 1, all respondents (100%) confirmed that transferring data from paper to Excel is time-consuming and redundant. The same proportion reported excessive paper usage due to printed checklists and difficulty in managing handwritten notes during site inspections. Furthermore, 80% of the participants indicated frequent challenges in retrieving past entries due to the absence of centralized digital records. Importantly, all respondents expressed openness to adopting a digital platform for future assessments.

These findings provide clear justification for the development of a mobile-based quality assessment tool. The consistent responses point to critical inefficiencies in the manual process that compromise productivity, accuracy, and data accessibility.

3.2 Evaluation of Application Effectiveness

The third objective aimed to assess the effectiveness of the PROSPECT application compared to traditional manual methods. A structured Likert-scale survey was distributed to 30 site personnel following the implementation of the digital platform. Seven performance categories were evaluated: usability, accessibility, efficiency, data entry, output quality, paper usage, and

sustainability. To evaluate the statistical significance of the observed improvements, a paired sample t-test was conducted.

This test was used to compare user ratings before and after the implementation of the application. The results are shown in Table 2.

Table 2: Paired Sample t-test

Category		**Pre-Mean Post-Mean**	**Mean Difference**	**Std Deviation**		**t-value p-value**
Usability	2.50	4.53	2.03	0.183	61.00	<0.001
Accessibility	2.50	4.60	2.10	0.403	28.57	<0.001
Efficiency	2.53	4.40	1.87	0.346	29.57	<0.001
Data Entry	2.43	4.53	2.10	0.305	37.70	<0.001
Output Quality	2.53	4.47	1.94	0.183	61.00	<0.001
Paper Usage	2.50	4.57	2.07	0.183	59.00	<0.001
Sustainability	2.53	4.57	2.04	0.320	34.82	<0.001
Average	**2.50**	**4.52**	**2.02**	**0.275**		

Table 2 presents the results of the paired sample t-test, which compares the pre-development mean (pre-mean) and post-development mean (post-mean) scores across all evaluated categories. The highest t-values were recorded in usability and output quality, both at 61.00, indicating exceptionally strong improvements in these two aspects following the introduction of the PROSPECT application. These high values demonstrate that users experienced a major enhancement in how easily they could conduct inspections and in the consistency of report generation.

The table also shows an average mean difference of 2.02, reflecting a substantial shift in user perception between the manual method and the digital platform. This value signifies that respondents consistently rated the application more favourably across all seven categories. Furthermore, the standard deviation of 0.275 suggests minimal variation in user responses, which indicates that the improvements were uniformly experienced across the respondent group. Collectively, these results confirm the effectiveness of the application in addressing the limitations of the manual process and improving on-site quality assessment practices.

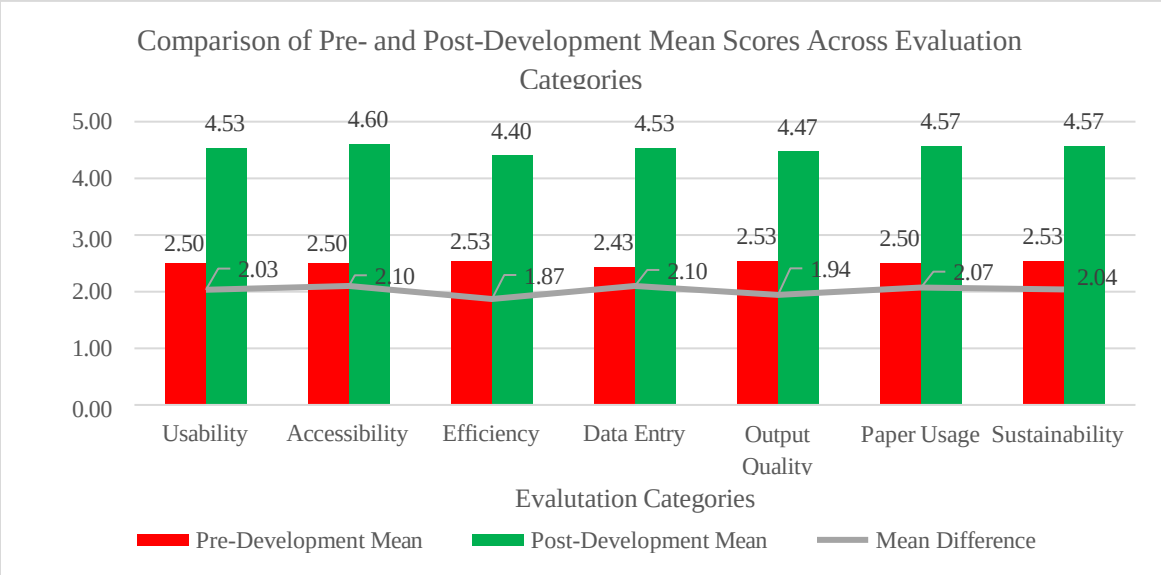

Figure 3: Comparison of pre- and post-development mean scores across seven evaluation categories using a 5-point Likert scale.

Figure 3 illustrates the comparison of pre-development mean (pre-mean) and post development mean (post-mean) scores across the seven evaluation categories. The post-mean scores for all categories exceed 4.40, falling within the "very high" range, while pre-mean scores remain below 2.60, categorized as "low." This graphical representation reinforces the statistical findings in Table 2, clearly showing the effectiveness of the PROSPECT application in improving usability, efficiency, and sustainability in structural assessment practices.

Table 3: Cohen's d effect sizes for pre- and post-development comparisons

Category	**Cohen D**	**Effect Size Interpretation**
Usability	11.14	Very Large
Accessibility	5.22	Very Large
Efficiency	5.40	Very Large
Data Entry	6.88	Very Large
Output Quality	11.14	Very Large
Paper Usage	10.77	Very Large
Sustainability	6.36	Very Large

The effect size analysis in Table 3 confirms that all seven evaluation aspects demonstrated very large effects, further validating the impact of the PROSPECT application. Notably, usability and output quality recorded the highest effect sizes at 11.14, signifying that users experienced substantial practical improvements in how they perform and report inspections using the digital tool.

It is noteworthy that all Cohen's d values far exceed the conventional threshold of 0.8 for a large effect, with the lowest recorded at 5.22. According to Cohen (1988), values above 0.8 are already considered large, thus values in this study indicate extraordinarily strong effects. This can be attributed to the combination of large observed mean differences and low variability among user responses. Such high effect sizes suggest that the improvements introduced by the PROSPECT application were not only statistically significant but also consistently experienced and practically transformative across all categories of assessment.

3.3 Discussion

The findings of this study reveal a significant advancement in quality assessment practices following the implementation of the PROSPECT mobile application. Through both descriptive and inferential analyses, the results confirmed that transitioning from paper-based checklists to a digital platform leads to substantial improvements in usability, efficiency, and compliance monitoring. These findings are not only statistically significant but are also practically meaningful, with all post-development evaluation categories falling within the "very high" range and supported by large effect sizes.

One of the most compelling outcomes was the drastic improvement in usability, as users found the application intuitive, responsive, and well-integrated with site workflows. This aligns with Madan and Dubey (2012), who emphasized the necessity of usability in determining the effectiveness of digital tools in engineering environments. The consolidated interface allowed for direct data entry during inspection and eliminated redundant documentation steps, a sentiment echoed by Kirakowski and McNamara (2006) who identified streamlined functionality as central to positive user experience.

Furthermore, efficiency saw a notable increase, as respondents confirmed that the application reduced the time spent on inspections by automating scoring and eliminating the manual transfer of notes into Excel. This reinforces the claims made by Luo et al. (2022) and Zhou et al. (2021), who found that digital tools reduce inspection cycle time and support faster, more accurate decision-making. The study also validated the app's real-time reporting capability, as supported by Firebase's infrastructure, which enabled instantaneous data synchronization, as highlighted in Chowdhury et al. (2019) in their study on digital productivity in construction.

A particularly important finding relates to paper usage and sustainability, where all participants agreed the application drastically reduced printed materials. This supports the literature by Ameen (2019) and Elagroudy et al. (2023), who assert that mobile digital solutions in construction promote sustainable resource consumption and align with SDG 12 (Responsible Consumption and Production). The implications here are not merely operational but extend to corporate environmental responsibility and long-term process optimization.

The significance of this study lies in its ability to empirically demonstrate that mobile-based solutions are not just feasible but highly effective for structural quality assessments in real construction settings. Previous studies such as Askar et al. (2023) and Kassem and Al-Sharqi (2022) have advocated for the digitalization of quality management, but empirical, on-site validation has been limited. This study addresses that gap by not only developing the

PROSPECT application but also testing it in an active residential project environment with feedback from multiple stakeholders involved in site-level execution.

Moreover, the findings offer practical implications beyond usability. For example, accessibility improvements ensure inspectors can retrieve past records on-site without relying on paper files or offline Excel sheets. This resolves a major issue identified during the problem identification stage, where 80% of participants cited difficulty in clarifying previous entries due to the lack of centralized records. In terms of interpretive significance, the high t-values and Cohen's d effect sizes suggest that the improvements are not due to chance or novelty but rather indicate a fundamental transformation in how quality control can be executed. The very large effect sizes reported across all categories confirm that the digital tool did not just marginally improve processes but shifted the operational baseline. There were no contradictions between the findings and the hypotheses of the study. On the contrary, the results strongly support the hypothesis that a digital tool designed in alignment with industry standards such as CIDB CIS 7:2014 can significantly enhance structural quality assessments in the field.

Overall, the findings highlight the relevance and urgency of embracing mobile digital platforms in the construction industry. As project complexity increases and demands for compliance intensify, tools like PROSPECT serve as scalable solutions for ensuring quality, transparency, and sustainability. This study not only validates prior scholarly claims but also contributes new empirical evidence supporting digital transformation in quality assurance.

4.0 CONCLUSION

This study set out to address the limitations of the manual OSK Quality Standard (OQS) Assessment process by developing and evaluating a mobile-based application, PROSPECT, aimed at improving efficiency, accuracy, and sustainability in structural quality assessments. Based on the findings from both descriptive and inferential analyses, it can be concluded that the digital application significantly enhances quality control practices when compared to the conventional paper-based method.

The implementation of the PROSPECT application led to measurable improvements across all evaluated aspects, including usability, accessibility, efficiency, data entry, output quality, paper usage, and sustainability. Notably, the highest t-values were recorded in usability and output quality, indicating that users experienced substantial gains in ease of use and standardized reporting. The average mean difference of 2.02 and low standard deviation further reinforce the consistency and strength of user agreement regarding the application's impact.

The practical implications of this study are considerable. The findings demonstrate that mobile digital tools can not only streamline on-site assessment workflows but also promote environmentally responsible practices by eliminating excessive paper use. Additionally, by integrating standardized criteria such as those outlined in CIDB CIS 7:2014, the application supports compliance with regulatory requirements while improving documentation quality.

From a broader perspective, the success of this project suggests that digitalization in construction quality management is both feasible and highly beneficial. Organizations seeking to enhance their quality assurance operations should consider adopting similar digital solutions tailored to their internal standards and workflows.

However, this study also presents opportunities for further research. Future work could explore long-term deployment of the application across multiple project sites and assess its integration with other construction management systems such as Building Information Modelling (BIM) or Common Data Environment (CDE) platforms. Moreover, expanding the evaluation to include productivity metrics, defect reduction rates, or stakeholder satisfaction scores would provide a more comprehensive understanding of the application's impact.

In summary, the PROSPECT application offers a validated and replicable model for improving structural quality assessments through digitalization. It addresses key inefficiencies in the current manual process and sets a precedent for further innovation in construction quality control practices.

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Smart Filter Water Tank System for Construction Site

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ABSTRACT

The construction industry faces increasing challenges related to water wastage and contamination due to inefficient water management practices on-site. This study focuses on addressing these challenges at the Sunway City Ipoh Mall construction site by developing a Smart Filter Water Tank System. The main aim of this research is to design and evaluate a system that integrates multi-stage filtration technology with Internet of Things (IoT) capabilities to recycle wastewater for non-potable use, thus reducing dependency on freshwater sources. The study employed a comprehensive methodology, including site observations, stakeholder interviews, and water quality testing to identify key issues and validate the system's effectiveness. Results showed significant improvements in water quality, with over 80% reduction in turbidity and consistent pH stabilization within the neutral range. The system's real-time monitoring and automated filtration also enhanced operational efficiency and ensured compliance with environmental standards. Stakeholder feedback confirmed the system's practicality and potential for wider implementation in construction projects. This study concludes that smart water management systems offer a viable solution for sustainable construction and recommends further adaptation of such technology in similar projects to promote environmental responsibility and cost efficiency.

Keywords: smart filtration system, water management, construction site, sustainable practices, IoT

1.0 INTRODUCTION

The construction industry is evolving rapidly with a heightened emphasis on sustainability, operational efficiency, and environmental responsibility. Among the critical issues affecting modern construction practices is water management, especially given the substantial volume of water required for activities such as concrete mixing, equipment cleaning, and dust suppression. Despite its importance, water is often mismanaged at construction sites, leading to significant wastage and contamination. These inefficiencies pose environmental risks and financial burdens, particularly on large-scale projects such as the Sunway City Ipoh Mall.

Conventional water management approaches typically involve manual processes that are labour-intensive and prone to human error. Moreover, such methods often lack real-time monitoring and automated control, making them ineffective in addressing dynamic on-site water quality issues. At the Sunway City Ipoh Mall construction site, for instance, there was evident overconsumption of water and minimal treatment or reuse mechanisms in place. The absence of efficient recycling systems exacerbates the environmental footprint and increases operational costs due to the continuous need for fresh water and off-site wastewater disposal.

In response to these challenges, this study introduces the development of a Smart Filter Water Tank System. This innovation integrates multi-stage filtration with Internet of Things

(IoT) technology to facilitate the recycling of wastewater for non-potable use. The aim is to reduce reliance on freshwater sources while ensuring compliance with environmental standards through real-time monitoring and automated control of water quality parameters.

The relevance of this research is further substantiated by existing literature. Numerous studies have emphasized the urgent need for improved water management in the construction industry, highlighting the environmental degradation and cost inefficiencies caused by poor water practices (Memon, Rahman, & Aziz, 2010; Silva & Costa, 2023). Regulatory bodies and environmental agencies have issued frameworks to promote sustainable water use and enforce compliance (Environmental Protection Agency, 2021; Economic Planning Unit, Malaysia, 2020), while industry leaders advocate for the adoption of best practices such as on-site recycling, effective treatment methods, and rigorous monitoring (Construction Industry Development Board, 2023).

Smart filtration technologies have emerged as promising tools in this context. These systems employ advanced treatment methods, including sediment filtration and activated carbon processing, to purify wastewater to a standard suitable for reuse (Chen, Wang, & Zhang, 2019). Moreover, integration with IoT allows for continuous assessment and adjustment of system operations, ensuring efficiency and adaptability to varying site conditions (Guan, Li, & Xu, 2020). The benefits extend beyond environmental protection to include regulatory compliance, reduced water procurement costs, and enhanced site productivity (Rana & Vyas, 2018).

Sustainable construction practices underscore the necessity of integrating technologies like smart filtration systems. By minimizing resource consumption, reducing pollution, and improving waste management, such innovations contribute significantly to achieving environmentally responsible construction goals (Bakar & Hashim, 2021; Tan & Lee, 2020). However, despite the evident advantages, gaps remain in widespread adoption due to technical limitations and compliance challenges (World Bank, 2021; Zhou & Wu, 2020).

This study seeks to bridge those gaps by designing and evaluating a tailored Smart Filter Water Tank System suited for application in active construction environments. Through site-specific data collection, stakeholder engagement, and rigorous testing, the project aims to offer a scalable, effective, and sustainable solution to water management challenges in the construction sector.

2.0 METHODOLOGY

This research adopts a systematic methodology to develop and evaluate the Smart Filter Water Tank System for the Sunway City Ipoh Mall construction site, structured into four phases. Phase 1, Problem Statement, involves analyzing existing water management practices through site observations and stakeholder interviews to identify issues related to water wastage and quality. Phase 2, Data Collection, focuses on gathering comprehensive data, including conducting site observations and water quality testing to establish baseline metrics. Phase 3, System Design, entails designing the prototype of the Smart Filter Water Tank System, ensuring it meets the identified needs and specifications. Finally, Phase 4, Prototype Development and Testing, involves implementing the prototype, assessing its effectiveness in

reducing water wastage, improving water quality, and promoting sustainable construction practices. Figure 1 illustrates the framework of this study.

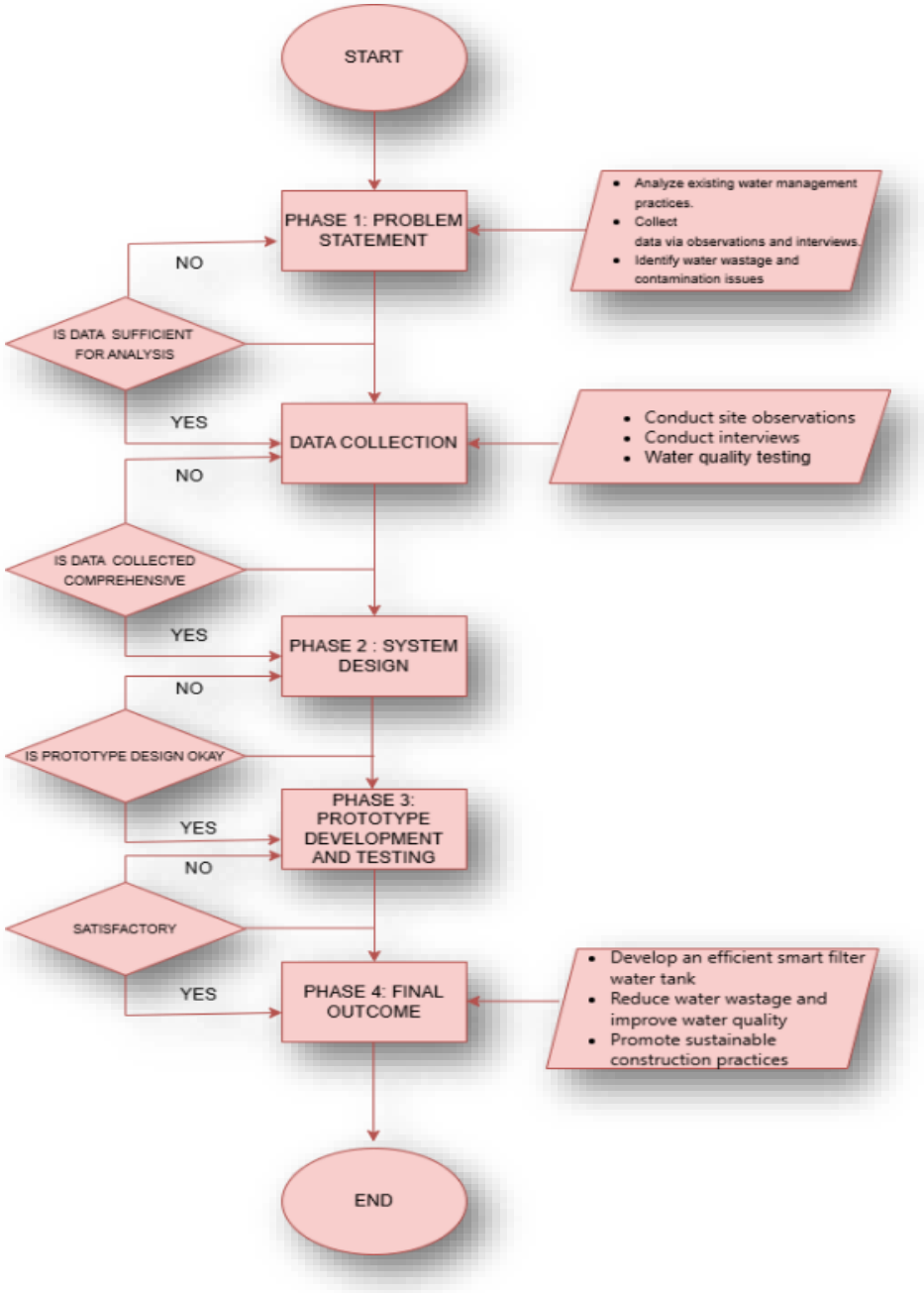

Figure 1: Methodology Flow Chart

2.1 DATA COLLECTION APPROACH

The data collection approach for this study was systematically designed to ensure a thorough analysis of water management challenges at the Sunway City Ipoh Mall construction site. This

process utilized three primary methods: site observations, stakeholder interviews, and water quality testing.

Site observations focused on identifying inefficiencies in water usage during construction activities such as concrete mixing, equipment cleaning, and dust suppression. Observational data highlighted the extent of water wastage and contamination, providing critical insights into areas requiring intervention. In parallel, structured interviews were conducted with key stakeholders, including project managers, engineers, and site workers, to gather qualitative insights into existing water management practices, challenges faced, and expectations for the proposed filtration system. Feedback from these stakeholders was instrumental in refining the system design, ensuring it was practical, efficient, and aligned with the specific needs of the construction site.

To complement these qualitative insights, water quality testing was carried out to evaluate the physical and chemical properties of water at various points on-site, particularly in areas prone to runoff. Key variables measured included pH levels (to assess acidity or alkalinity), turbidity (to quantify water cloudiness), and the presence of chemical contaminants such as heavy metals and oils. Advanced analytical tools were employed to ensure the accuracy and reliability of these measurements, which were essential for designing an effective filtration system tailored to the site's needs.

The combination of observational data, stakeholder input, and rigorous water quality testing provided a robust foundation for the development of the Smart Filter Water Tank System. This comprehensive approach not only ensured that the proposed system addressed site-specific challenges but also aligned with regulatory requirements and sustainability objectives in water management.

Table 1: Water Record Data Variables: Indicators for Monitoring Water Quality in Construction Sites (Zhou & Wu, 2020; Zheng & Wong, 2022)

Water Record Data Variables		
Variable	**Description**	**Unit of Measurement**
Water Quality (pH)	Measurement of the acidity or alkalinity of the water	pH units
Turbidity	Measurement of the cloudiness of water, indicating the presence of suspended particles	Nephelometric Turbidity Units (NTU)
Chemical Contaminants	Concentration of chemicals or pollutants in the water (e.g., heavy metals, oils, etc.)	Milligrams per liter (mg/L)

2.2 SYSTEM DESIGN AND TESTING

The Smart Filter Water Tank System has been meticulously developed to address the water management challenges at the Sunway City Ipoh Mall construction site, integrating advanced

multi-stage filtration technology with Internet of Things (IoT) capabilities. The system features a comprehensive three-stage filtration process: first, sediment filtration removes large particles such as sand and debris; second, activated carbon treatment eliminates chemical impurities and odors, and third, fine filtration enhances water clarity. These processes ensure that the treated water meets high-quality standards, rendering it suitable for reuse in essential construction activities such as equipment cleaning and dust suppression.

To further enhance its functionality, IoT sensors are embedded within the system to continuously monitor key water quality parameters, including pH levels, turbidity, and the presence of chemical contaminants. This real-time data allows for automatic adjustments to the filtration process, ensuring consistent performance, compliance with environmental regulations, and operational efficiency.

The prototype has undergone rigorous testing under simulated construction site conditions. Results from these tests indicate that the system effectively recycles significant volumes of water used on-site, thereby reducing reliance on freshwater sources and minimizing wastewater discharge. Its modular and scalable design facilitates adaptability across various construction environments, making it a versatile and sustainable solution for water management.

Overall, the Smart Filter Water Tank System represents an innovative approach to addressing critical water management challenges. Its successful implementation has the potential to set a benchmark for sustainable and environmentally responsible practices within the construction industry.

2.3 DATA ANALYSIS METHOD

The data analysis method employed in this study was designed to evaluate the performance and effectiveness of the Smart Filter Water Tank System, utilizing both quantitative and qualitative approaches. This comprehensive analysis aimed to assess the system's impact on water quality and its operational efficiency.

Initially, quantitative data collected from water quality testing were analysed using statistical methods to determine the effectiveness of the filtration processes. Key parameters, including pH levels, turbidity, and concentrations of chemical contaminants, were compared against baseline metrics obtained prior to system implementation. Statistical analysis techniques, such as descriptive statistics and inferential statistics, were employed to identify trends, variations, and improvements in water quality post-treatment. This analysis provided measurable evidence of the system's performance in enhancing water quality for reuse in construction activities.

In addition to quantitative analysis, qualitative data gathered from stakeholder feedback during the testing phase were systematically reviewed. The insights from project managers, engineers, and site workers were categorized into themes related to usability, operational efficiency, and overall satisfaction with the system. This thematic analysis allowed for a comprehensive understanding of user experiences and perceptions, highlighting both strengths and areas for improvement.

The combination of quantitative and qualitative data analysis enabled a holistic evaluation of the Smart Filter Water Tank System. This dual approach not only confirmed the system's effectiveness in improving water quality but also ensured that it addressed the practical needs and concerns of stakeholders, thereby enhancing the overall success of the implementation.

3.0 RESULT AND ANALYSIS

This chapter presents the results and analysis of the Smart Filter Water Tank System developed for the Sunway City Ipoh Mall construction site. The system was designed to address significant challenges related to water wastage and contamination, prevalent in large-scale construction projects. The outcomes are evaluated based on water quality improvement, system functionality, operational efficiency, and stakeholder feedback.

3.1 WATER QUALITY IMPROVEMENT

The implementation of the Smart Filter Water Tank System resulted in substantial improvements in water quality. Quantitative data collected from water quality testing before and after the system's integration revealed significant reductions in turbidity and stabilization of pH levels. For instance, turbidity levels decreased by over 80%, while pH values were consistently maintained within the neutral range (approximately 7.0 to 7.2). These results confirm the system's effectiveness in purifying water for reuse in construction activities

Table 2: Comparison of Conventional System vs. Smart Filter Water Tank System

(March) By Week	Parameter	Conventional System	Smart Filter System	Improvement (%)
Week 1	**pH Level**	Not Recorded	7.0	Improvement to neutral level
	Turbidity (NTU)	158	26	83.5%
	Chemical Contamination	High	Low	Significant reduction
Week 2	**pH Level**	Not Recorded	7.1	Improvement to neutral level
	Turbidity (NTU)	165	25	84.8%
	Chemical Contamination	High	Low	Significant reduction
Week 3	**pH Level**	Not Recorded	7.0	Improvement to neutral level
	Turbidity (NTU)	170	28	83.5%
	Chemical Contamination	Very High	Low	Major reduction
Week 4	**pH Level**	Not Recorded	7.2	Improvement to neutral level
	Turbidity (NTU)	162	24	85.2%
	Chemical Contamination	High	Low	Significant reduction

3.2 SYSTEM FUNCTIONALITY AND OPERATIONAL EFFICIENCY

The operational efficiency of the Smart Filter Water Tank System was evaluated through its functionality during the testing phase. The integration of IoT sensors enabled real-time monitoring of key water quality parameters, allowing the system to make automated adjustments to the filtration process based on continuous feedback. This feature ensured consistent performance, enhanced reliability, and compliance with regulatory water quality standards. Figure 2 presents the graphical results obtained from the product effectiveness questionnaire, highlighting user feedback on various performance indicators of the system.

The graph comprises eight evaluation plots, each assessing a specific aspect of the system, including water quality improvement, operational efficiency, environmental impact, and usability. Ratings were based on a scale from 1 (Not Significant) to 4 (Extremely Significant), indicating the frequency of responses for each parameter. The system's ability to improve water quality received the most favourable ratings, with the majority of respondents selecting scores of 3 and 4. Similarly, operational efficiency and monitoring accuracy were highly rated, demonstrating confidence in the system's ability to perform consistently and monitor water quality effectively.

Moderate ratings were observed in areas such as water wastage reduction and ease of operation, primarily ranging between scores 2 and 3. This indicates that while the system is generally effective and user-friendly, there is still room for refinement to improve its performance and ease of use. The system's impact on construction efficiency was also viewed positively, reflecting its supportive role in improving site operations. Furthermore, strong ratings for environmental compliance and broader applicability suggest that users recognize the system's alignment with sustainability standards and its potential for implementation in various construction contexts. Overall, the results confirm that the Smart Filter Water Tank System is a practical and effective solution, aligning with the project's objectives to enhance water management and promote sustainable construction practices.

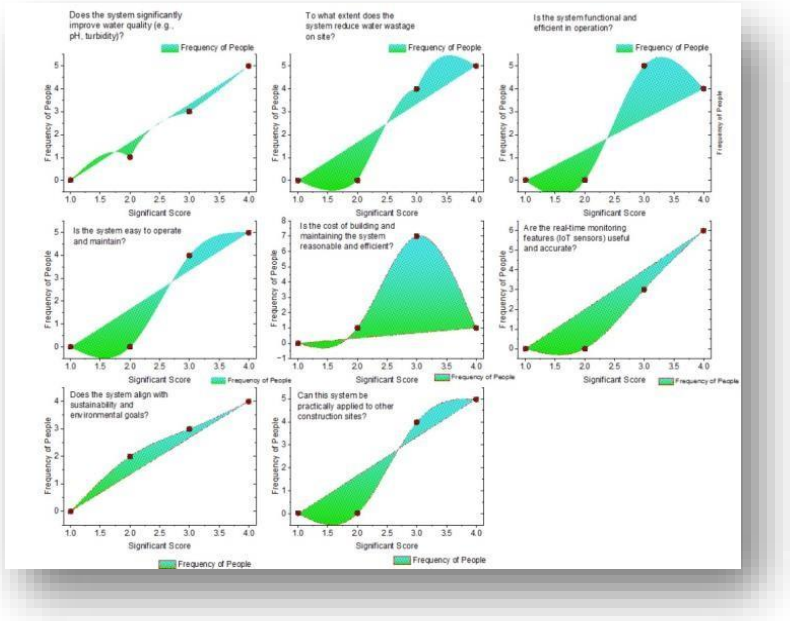

Figure 2: Graphical results from the product effectiveness questionnaire

3.3 COMPARATIVE ANALYSIS

A comparative analysis was carried out to assess the differences between conventional water management practices and the implementation of the Smart Filter Water Tank System at the Sunway City Ipoh Mall construction site. Traditional methods were found to rely heavily on direct freshwater consumption for construction activities such as concrete mixing, dust suppression, and equipment cleaning. These methods typically lacked proper treatment systems for wastewater, resulting in high water wastage and the uncontrolled release of pollutants into the environment. Furthermore, monitoring of water usage and quality was done manually, which increased the risk of human error and inefficiencies.

In contrast, the Smart Filter Water Tank System introduced a more sustainable and efficient approach to water management. One of the key outcomes was the significant improvement in water quality. The system effectively reduced turbidity and removed chemical contaminants such as oils and suspended solids, making the treated water suitable for non-potable reuse on site. This helped reduce dependency on external freshwater sources.

In terms of operational efficiency, the system featured automated filtration processes and real time monitoring using IoT sensors. This allowed for continuous tracking of key water quality parameters, enabling timely interventions and reducing the need for manual oversight. The system was also designed with modular components, allowing it to be deployed flexibly across different areas of the construction site.

From a cost perspective, the Smart Filter Water Tank System contributed to noticeable savings. By recycling water on-site, the project reduced expenses related to freshwater procurement and external wastewater treatment services. Additionally, the system's automated alerts helped prevent equipment failures and minimized maintenance costs.

Overall, the Smart Filter Water Tank System demonstrated clear advantages over conventional practices in terms of water quality, operational efficiency, environmental impact, and cost-effectiveness. These improvements highlight the potential of smart water management systems to support sustainable construction practices and enhance resource efficiency on-site.

Table 3:Summary of Comparative Benefits

Parameter	Conventional Practices	Smart Filter Water Tank System
Freshwater Usage	High	Significantly Reduced
Wastewater Treatment	Minimal or Absent	Integrated and Automated
Monitoring Method	Manual	Real-time IoT-based
Environmental Impact	High	Low
Operational Cost	High	Reduced

4.0 CONCLUSION AND RECOMMENDATIONS

The development and implementation of the Smart Filter Water Tank System at the Sunway City Ipoh Mall construction site have effectively addressed key challenges related to water wastage and contamination in the construction industry. The integration of multi-stage filtration and Internet of Things (IoT) technologies enabled the system to significantly enhance water quality, with results showing more than an 80% reduction in turbidity and consistent

stabilization of pH levels within the neutral range. These improvements made the recycled water suitable for non-potable reuse, supporting essential site operations such as equipment cleaning and dust suppression while reducing reliance on external freshwater sources.

In addition to improving water quality, the system demonstrated notable operational advantages. The real-time monitoring capabilities provided by IoT sensors allowed for continuous tracking of key parameters and automated adjustments, ensuring efficiency, reliability, and compliance with environmental standards. Comparative analysis revealed that the Smart Filter Water Tank System outperformed conventional water management practices in areas such as cost efficiency, environmental impact, and system usability. Positive feedback from stakeholders further validated the system's practicality and potential for broader application across diverse construction environments.

Given these findings, it is recommended that similar smart water management systems be adopted in other large-scale construction projects to promote sustainability and resource efficiency. Future improvements should focus on enhancing modularity for diverse site conditions and integrating renewable energy sources to increase environmental benefits. Moreover, collaboration between industry practitioners and policymakers is encouraged to support the widespread adoption of such technologies through incentives, regulations, and knowledge-sharing platforms aimed at fostering environmentally responsible construction practices.

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2 TEKNOLOGI KEJURUTERAAN PEMBUATAN (PENGURUSAN RANGKAIAN BEKALAN)

Defect Identification Process In Production Line

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ABSTRACT

This study looks into the underlying reasons for company high product rejection rate, which routinely surpasses the 0.8% target. By employing the Root Cause Analysis (RCA) method to improve employee productivity and machine performance, the primary goal is to lower the rejection rate. This research holds its potential in reducing material waste, improving product quality and maximising production efficiency of a high precision manufacturing environment, and henceforth noteworthy; main causes of defects were determined using Systematic RCA, involving operators' interview, quality control (QC) record analysis and observational evaluation. The study found that inaccurate internal diameter (ID) measurements, irregular outer diameter (OD) checks, contamination of coolant and dependence on nonstandard measuring instruments were the persistent problems. In order to address these, specific improvements included a dedicated storage tray of pin gauges, training of the operators to use micrometre, scheduled inspections five times a day and introduction of three pin gauging systems (Go Fit, Go Loose and No Go) to overcome the deficiencies. Taking these steps reduced the rejection rate steadily until October, when we saw a reduction from 1.1% to 0.506% and hit the desired rate, and the study concludes that RCA based tactics can decrease the rejection rate and suggests their usage in other departments with quality control issues similar to theirs if done continuously along with employees involvement.

Keywords: machine performance, quality control, root cause analysis, product rejection, and operator efficiency

1.0 INTRODUCTION

To achieve excellence, cut down on costs, and meet customers' demands, quality control cannot be overlooked in the very competitive manufacturing area. A single small issue can cause serious financial problems, disappoint customers, and do damage to someone's good name. For this reason, focusing on high quality and rejecting fewer products is very important for a business, not only for technical reasons. In order to stay ahead and supply excellent products, businesses should regularly evaluate and change their ways of producing goods.

The rejection rate for products in a precision engineering company that covers industrial equipment, automotive, oil and gas, and medical sector is often more than 0.8%, even though this is higher than the company's goal. The high number of defective items leads to waste and adds to the company's expenses, and it also delays and reduces the amount of work done. For this issue, an orderly and data-based approach was needed to determine its main reasons and address them properly.

The purpose of starting this project was to find tactics to minimize rejections and was included in the organization's developing quality improvement plan. It was pointed out that worker capability, inspector performance, and the way measuring tools are used, represent important features of employee efficiency. Similarly, maintaining the machines properly and securing accuracy, must be applied to machine performance.

The goal was to use the RCA technique to find the reasons behind quality problems that happened several times. Because RCA is thorough, it becomes simpler to spot problems that are happening beneath the surface rather than just things that can be seen. To better recognize the rejection patterns, observation, QC information, and comments from operators were used together.

In this paper, the work done in the initial phase of the project to highlight key quality issues and introduce suitable improvement plans is covered. It demonstrates that using a standard approach powered by accurate data and togetherness between teams enhances quality performance. Lowering the rejection rate to less than 0.8% and promoting sustainable ways of production ensures that quality in productions is ensured from the start.

2.0 METHODOLOGY

For this study, identifying the reasons behind many product returns was mainly based on the use of Root Cause Analysis (RCA). The reason RCA was used is that it stresses the search for root issues instead of just working on superficial symptoms. There were several steps in the methodology: first, collect the data, next identify the issue, analyse the root of the problem, propose solutions, and review the outcomes.

For the results to be correct and trustworthy, the data was gathered using multiple approaches. To spot any flaws or productivity issues in dimensional inspection tasks, I personally watched production on the floor at the time when work was happening. Next, to see what issues were most common, their sites, and which products they affected, the organization looked at quality control (QC) records and the reasons for rejecting products. In addition, conversations with supervisors and workers helped to see how they dealt with the problems they encounter during the measurement and inspection stages.

Using both approaches showed that there are many similar problems in these countries. These comprised:

- Incorrect ID measurements tend to happen if the calibration process is not done correctly or the right pin gauges are not put in place.
- Because of poor ways of using micrometres and no scheduled in-process checks, the outer diameter (OD) was not always checked accurately.
- Dimensions and the quality of the surfaces deteriorated because of coolant contamination.
- based on methods that involved old instruments or those which didn’t accurately fit the specifications, mostly used in smaller measurements.

When tiny deviations could make a product unsuitable, these issues were considered very important.

After noticing the reasons behind the problem, a range of solutions were designed and implemented. Some of the people included in their work were:

- A structured pin gauge system with three types Go Fit, Go Loose (2 micron oversized), and No-Go was introduced especially for parts that need tolerances of less than 6 microns.
- Improved inspection practices, including cross-checking pin sizes during shift changes and regular (hourly) visual inspections.
- programs that teach operators how to handle micrometres correctly, calibrate zero points, and comprehend measurement tolerances according to technical drawings.

- Pin gauges should be stored in a special location to avoid loss or mixing and to encourage more methodical tool handling.

How well these interventions worked was determined by checking the rejection rate both before and after. After the implementation phase, monthly records of defects were gathered and compared to check the trend.

3.0 RESULTS AND DISCUSSION

It was noticed that the new strategies had a positive effect on both the way products are made and their overall quality. To ensure an accurate and trustworthy assessment of critical parts with very high accuracy demands, pin gauges–Go Fit, Go Loose, and No-Go–were one of the main interventions needed. This intervention especially aimed to solve the serious issue caused by past inaccurate dimensional measurements and the high rates of discarded parts. With the pin gauges, the process was made more reliable because it was harder to measure parts that only slightly varied from the requirements.

Besides, those who ran the equipment went through training focused on correctly using micrometres. Especially, the training asked apprentices to take care with delicate tools, learn to pick out errors in measurement, and practice reading off the small scales on micrometres correctly. The operators improved their precision and attitude while carrying out dimensional inspections. Due to the help from AI, inspectors made fewer mistakes and gave better results.

A checklist was organized to ensure quality control, so that operators must inspect the visual and OD aspects of the part at least five times in a day. The regular checks on size helped detect any problems fast so they could be dealt with promptly. So that these key instruments aren't damaged from mixing up, a tray was built just for pin gauges. Taking care of the gauges made sure that the instrument readings did not change randomly.

Table 3.0 below presents the rejection rates of each product, which show the effectiveness of using combined interventions. It can be clearly seen from the information in the table that after the actions, overall rate of rejections was reduced. In October, for example, the rejection rate reached a peak of 1.1%, well above the 0.8% target threshold. Nevertheless, the rejection rate significantly dropped to 0.506% in February following the implementation of the interventions, and it remained below the goal in the months that followed. This downward trend shows how the implemented improvements have improved the quality of the product.

Table 3.0: Rejection Rates for Monthly Products Before and After Improvements

	Month	OK (Units)	NG (Units)	Total Units	Rejection Rate (%)
BEFORE	September	1,202	10	1212	0.8
	October	2,095	23	2,118	1.1
	November	1,686	9	1,695	0.5
	December	387	3	390	0.8
AFTER	January	6,265	42	6,307	0.666
	Februrary	6,679	34	6,713	0.506
	March	4,283	32	4,315	0.742

In the meantime, Figure 3.1 provides a visual depiction of the improvements by graphically illustrating the rejection rate trends over the months under study. It is simpler to see the change in performance because the chart shows the time before and after the improvement strategies were put into practice. It is evident from the graphical data that rejection rates peaked prior to the

improvements, then steadily declined and stabilized below the acceptable limit following the interventions. By providing a clear visual representation of the benefits brought about by the Root Cause Analysis (RCA)-based improvement plan, this figure supports the quantitative evidence.

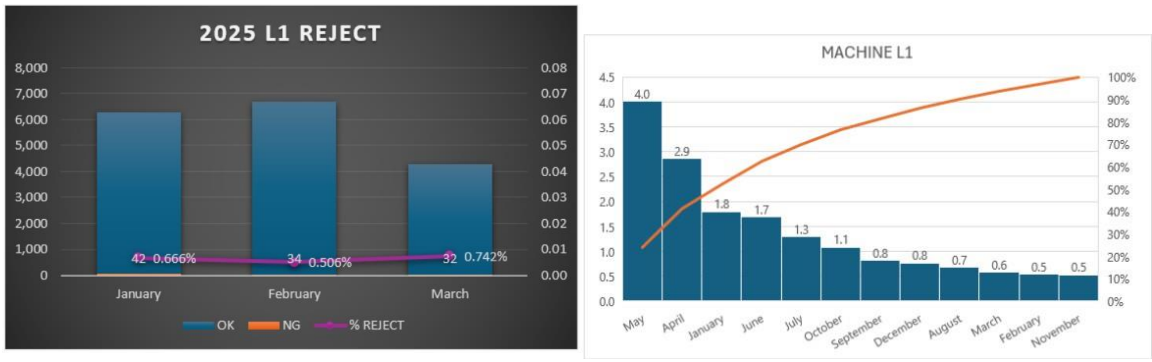

Figure 3.1: Trend Chart for Rejection Rate

In addition to the quantitative findings, operators' qualitative feedback suggested that the new procedures and systems were simpler to use and more successful at spotting product flaws early on. Operators said they were more satisfied and convinced about the equipment and methods used for inspection. Thanks to using more advanced equipment, providing specialized training, and making things more open in the way operations were run, production line productivity and consistency improved.

In short, the tables and graphs clearly prove that the results we see are due to the corrective actions taken and their straight application in the improvement process. Such results reveal that reducing product rejection and raising overall quality become possible when emphasis is put on precise instruments, trained workers, and frequent checking.

4.0 CONCLUSION

Application of a systematic quality improvement plan built on Root Cause Analysis (RCA) has dropped the product rejection rate to a significant extent. The investigation showed that the procedures for such measurements are not accurate enough, there is non standardization of measurement equipment and lack of frequency for measurement. When RCA was put to use, the team steered past superficial symptoms and started tackling root causes of product defects all the way to the core.

Standardization of measuring instrument, increasing of frequency and regularity of inspection and training of operators were among the interventions to ensure that the right measurement technology was used throughout the production process. These steps, however, effectively reduced the variability cause by human error and tooling inconsistencies. For example, standardized pin gauge protocols as well as implementing more frequent In Process Dimensional Checks helped reduce defects such as "No Go Enter" errors, as well as undersized components.

Focusing on these efforts, the product rejection rate, which had previously reached the peak rate of 1.1%, was reduced to below the company target threshold of 0.8%. This substantial reduction would allow fewer raw materials wasted and reworked resulting in saving costs. In addition, it enhanced the production flow, as well as customer satisfaction, with its higher quality products being consistently delivered.

Besides the reduction in defect rates, the program also resulted in the formation of a quality awareness mindset of the production team. The regular use of standardized tools and improvement in the operator competency and discipline in inspection procedures enforced a greater sense of accountability and attention towards product quality screams. This cultural shift was instead an assurance that quality was a core value in the ordinary manufacture processes instead of being a mere procedural necessity.

Considering this, this effective quality improvement project shows how data driven strategies and root cause analysis are helpful to resolve complex manufacturing problems. By focusing on the actual root causes and integrating the technical, procedural and human factors, Tsu Ru Engineering Works have managed to obtain long term quality improvement and operation excellence.

ACKNOWLEDGMENT

I would also like to express special thanks to my respected supervisor Dr. Woo, whose excellent guidance and comments together with endless encouragement have allowed me to finish this project. A deep understanding in manufacturing engineering and quality management was the main foundation for this study to succeed, particularly with relation to root cause analysis and process improvement strategy. His deep thoughts and unwavering supports shaped the way of research and the direction of research that made the research academically rigorous and practically relevant. Also, I would like to give my sincere thanks to for allowing me the access with all their facilities, resources, and real production data that were crucial to finalize this project. The readiness to engage and share [their] production challenges with the management and production teams and readiness to adopt the proposed improvements also showed great commitment to learning and continuous quality improvement. This initiative was welcomed opening by them that led to a meaningful study of defect causes and solutions in an industrial setting. Without the cooperation and trust of company and my supervisor, this project couldn't be at its best. Their combined support not only enriched my learning experience but also provided me with valuable exposure to practical engineering problem-solving in a professional environment.

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Development of a Real-Time Inventory Dashboard for Warehouse Efficiency

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ABSTRACT

This project investigates the inefficiencies in the current process of tracking customer orders, stock levels, and finished goods replenishment within the ASAP (ready stock) system at the Finished Goods Warehouse. The first objective is to identify key issues faced by planners, such as the inability to link customer bookings to specific stock, poor visibility of Customer Required Dates (CRDs), and difficulties in anticipating shortages or replenishment needs. These inefficiencies contribute to delays, miscommunication, and reduced warehouse performance. The second objective is to design a real-time, centralized warehouse dashboard that consolidates critical data points including customer orders, CRDs, inventory levels, and replenishment status. This dashboard is intended to serve as a visual decision-support tool for planners, offering user-specific access and real-time data updates. A design and development research method is applied to analyze current gaps and propose a solution framework using Google Looker Studio. While implementation is beyond the scope of this study, the proposed system is expected to reduce manual tracking efforts, improve data visibility, and support faster, more accurate planning decisions. The study concludes that the development of a centralized dashboard holds significant potential for improving warehouse efficiency and recommends further system integration and user testing for future enhancements.

Keywords: ASAP system, finished goods warehouse, Customer Required Date (CRD), inventory tracking, replenishment planning, centralized dashboard, Google Looker Studio

1.0 INTRODUCTION

1.1 Background Study

The development of a real-time inventory dashboard aims to address inefficiencies in warehouse operations, including poor visibility, manual tracking, and lack of coordination. By leveraging tools like Ishikawa diagrams and process mapping for problem identification, and Looker Studio for dashboard creation, this project seeks to enhance data visibility, communication, and inventory management.

Real-time inventory tracking systems provide instant updates on stock levels, enabling accurate inventory management and operational efficiency. These systems reduce errors associated with manual processes and improve decision-making by providing up-to-date information. Real time inventory management systems can help retailers to improve the customer experience by reducing stock outs, enhance operational efficiency, and thereby increase profitability through reduced costs due to overstocking (Immadisetty, 2025).

The Ishikawa diagram, also known as the fish bone diagram, is a cause-and-effect analysis tool used to identify root causes of inefficiencies. It systematically categorizes potential issues into major categories such as people, processes, materials, and equipment. This tool is effective in logistics for analyzing quality deviations and improving process outcomes. Fish bone diagram is part of a risk analysis technique that helps to pinpoint the causes of accidents and plot what actions need to be taken by way of cause and effect (Gür, 2024). When improvements are needed, working together as a team using tools like a fish-bone diagram can help find the main reasons behind problems. Understanding what causes a process or system to fail helps create

better and lasting solutions. This is especially important in healthcare, where making things better can have a big impact (Kumah, 2024).

Dashboards consolidate key metrics such as customer bookings, stock levels, and replenishment statuses into a centralized interface. Designing a good dashboard is important for making the most of real-time data in safety monitoring. A well-made dashboard shows clear and useful information, helping safety managers make smart decisions quickly. Dashboards that can be customized for different roles make it easier for everyone to see what's most important to them, making the dashboard more helpful and effective (Oluwaseyi Ayotunde Akano, 2024).

1.2 Objective

The current method of tracking customer orders, stock levels, and finished goods replenishment in the ASAP (ready stock) system at the Finished Goods Warehouse is not efficient. Planners have trouble seeing which customer bookings are linked to available stock, when items are needed (CRDs), and when stock will run low or be refilled. This lack of clear, real-time information causes delays, more manual work, and poor communication between teams. As a result, it becomes harder to plan properly and meet customer needs. To solve this problem, it is important to first identify the weaknesses in the current tracking process and then develop a real-time dashboard that helps planners and warehouse staff see and manage important data more easily. The main goal of this study is to create a smart warehouse management system (WMS) that uses IoT technology to improve how warehouses operate. This system aims to fix common problems in traditional warehouse management, like mistakes in inventory, manual errors, and difficulties in tracking stock. By using IoT devices, the system will provide real time data, automate inventory tracking, and help make better decisions (Madamidola, Daramola, & Akintola, 2024).

The objectives of this project are twofold. First, it aims to identify the key inefficiencies in the current process of tracking customer orders, stock levels, and finished goods replenishment within the ASAP (ready stock) system at the Finished Goods Warehouse. These inefficiencies include a lack of visibility, manual tracking efforts, and poor coordination among teams. Second, the project aims to develop a real-time, centralized warehouse dashboard that consolidates important data such as customer bookings, inventory levels, and replenishment status. The goal is to enhance data visibility, improve communication between departments, and support more efficient planning and inventory management. Managing inventory well is really important for businesses to keep up with customer needs, reduce costs, and run smoothly. Nowadays, many new technologies help make inventory management easier and more efficient (Vaka, 2024).

2.0 METHODOLOGY

2.1 Process Mapping

Process mapping is a useful way to study how things are done, especially in healthcare for improving quality. It helps show the steps needed to carry out a task, the order they happen in, and which steps are for the main goal versus other purposes. Process maps can also highlight differences in how the system works and find chances to make things run better. They often provide important information for other analyses, like studying how time is used to help calculate costs based on activities (Thomas I, Leah, & Ana J. , 2020).

In lean management, the word "Muda" is used to mean waste it's the Japanese term for it. Cutting down on waste brings big benefits to a company, like lower costs, better accuracy in

deliveries, and higher quality. Lean thinking says that getting rid of waste starts with the first "P," which is Philosophy. This means a company needs to have a strong mindset focused on reducing waste if they want to succeed in the long run. Also, many organizations have a lot of waste because their processes aren't consistent, causing different results and ways of working (Palm & Östling, 2024).

In the current planning workflow, the handling of ASAP orders involves multiple manual steps and communication channels. The process relies heavily on Excel dashboards and email correspondence between the Customer Service Group (CSG), planners, and warehouse staff. While the workflow generally ensures that customer inquiries are reviewed and responded to, there are several stages that involve manual tracking and follow-ups, which may cause delays, miscommunication, and inefficiencies. Understanding the existing process is crucial before proposing improvements to enhance visibility, speed, and collaboration among departments.

Refer to Figure 1, the process begins when the CSG inputs a customer inquiry or order into the Customer Technical Information (CTI) Excel Dashboard. The planner then receives and reviews the order using both the CTI dashboard and a confirmation email from the CSG. After reviewing, the planner checks stock availability through the ASAP Excel Dashboard to verify whether the required quantity of finished goods (FG) is available. If the stock is sufficient and the Customer Request Date (CRD) can be met, the planner proceeds to confirm the order with the CSG. However, if there is a shortage of FG, the planner must first contact the warehouse team to check if there are enough raw materials available for replenishment. Once raw material availability is confirmed, the planner follows up on the replenishment process. After ensuring that the stock can be replenished in time to meet the CRD, the planner sends a final confirmation to the CSG. This process, while functional, involves multiple manual checks, back-and-forth communication, and lacks a centralized system for real-time tracking and updates.

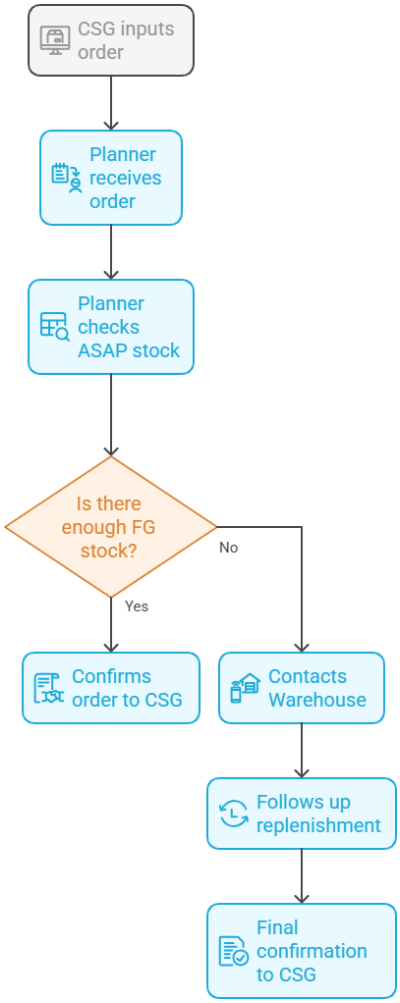

Figure 1: Current Process Flow

Figure 2, the proposed future process introduces a more efficient and integrated workflow by leveraging a centralized Looker Studio dashboard. The process begins with the Customer Service Group (CSG) entering customer orders into the Customer Technical Information (CTI) Excel dashboard, which is directly linked to the Looker Studio platform. This connection ensures that all relevant order details, including ASAP orders, Customer Request Dates (CRD), and stock status, are automatically updated and visible to the planners in real-time. Planners then review this consolidated dashboard to assess the availability of stock and the feasibility of meeting customer requirements. If replenishment of ASAP stock is necessary, planners can initiate and track this process promptly through the dashboard, eliminating the need for manual follow-ups and reducing delays. Once stock levels are confirmed and any necessary replenishment is underway or completed, planners send confirmation of the order back to the CSG. This streamlined process minimizes manual intervention, enhances communication, and improves data accuracy, ultimately resulting in faster response times and better coordination between departments.

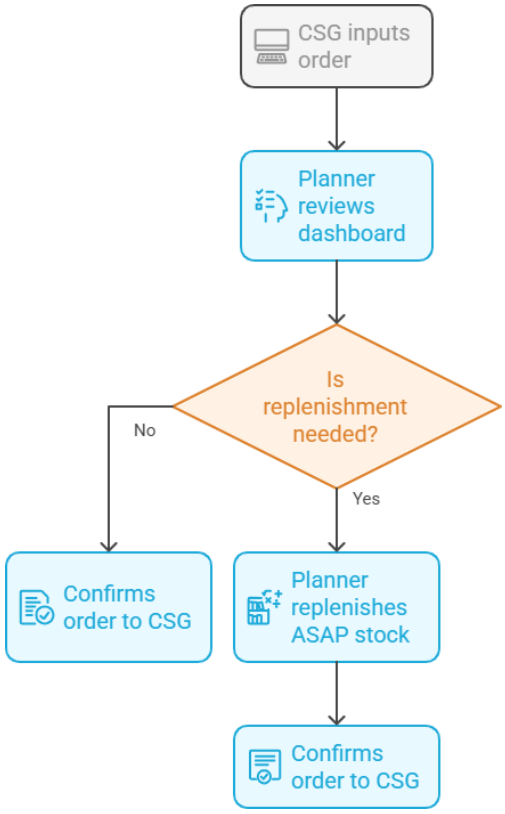

Figure 2: Future Process Flow

2.2 Ishikawa Diagram

The second method applied was the Ishikawa Diagram, also known as the cause-and-effect or fishbone diagram. This tool was used to systematically explore and categorize the possible root causes of inefficiencies. The analysis grouped issues into several major categories, including manpower, methods, machines, materials, and environment. Through brainstorming and discussions with relevant personnel, specific problems such as lack of real-time data access, manual tracking errors, communication gaps between departments, and delays in stock updates were identified. The Ishikawa Diagram helped visualize the complex relationships between different factors contributing to the current process issues.

Based on Figure 3, The Ishikawa Diagram was used to identify the root causes of inefficiencies in tracking customer orders, stock levels, and finished goods replenishment. The main problem inefficient warehouse tracking was broken down into four major categories:

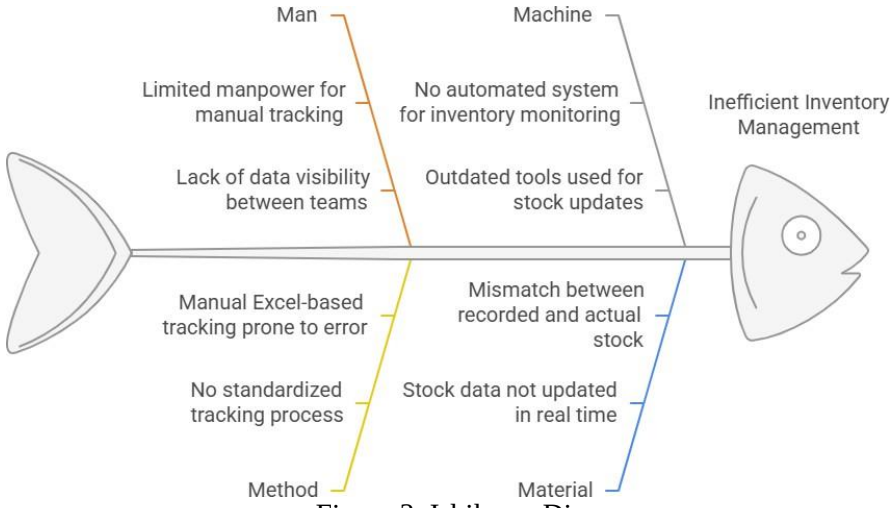

Figure 3: Ishikawa Diagram

Table 1: Table of Ishikawa Diagram

Category	Identified Causes
Man	- Limited manpower for manual tracking - Lack of data visibility between teams
Method	- No standardized tracking process - Manual Excel-based tracking prone to error
Machine	- No automated system for inventory monitoring - Outdated tools used for stock updates
Material	- Stock data not updated in real time - Mismatch between recorded and actual stock

This analysis helped uncover the key inefficiencies affecting the tracking process, which guided the dashboard development.

By combining the insights from both the process mapping and Ishikawa Diagram, a clearer understanding of the main problems was achieved. This thorough problem identification process provided a strong foundation for proposing improvements and guided the development of a real-time, centralized dashboard to address the identified inefficiencies.

2.3 Development of the Dashboard

After identifying the key inefficiencies in the current warehouse tracking process, the next step focused on designing and developing a real-time, centralized dashboard to improve data visibility and warehouse efficiency. The development process involved defining the dashboard requirements, designing the layout, collecting relevant data, and building the dashboard using Google Looker Studio.

As seen in Figure 4, The first step was to gather the functional requirements based on the issues found during the problem identification phase. Key data components identified for inclusion in the dashboard were ASAP customer orders, current stock levels, Customer Required Dates (CRDs), and replenishment status. Input from different users such as planners, warehouse staff, and the Customer Service Group (CSG) was considered to ensure the dashboard would be relevant and useful for all involved parties.

Once the requirements were clear, a layout was designed to ensure the dashboard would present information in a structured, easy-to-understand format. The real-time operational data was collected from existing warehouse and planning records to ensure accuracy and reliability. This data was then integrated into the dashboard to provide up-to-date insights on stock availability, order allocation, and replenishment progress.

Figure 4: Process Flow of Developing an Effective Dashboard

The dashboard was developed using Google Looker Studio, selected for its ability to connect to various data sources and create interactive, real-time visualizations. Data visualization using Looker Studio allows business owners to easily understand sales trends, ensuring accuracy and effectiveness in decision making. This tool is very useful for identifying seasonal patterns and supporting strategic decisions (Fauzi & Sutomo, 2025).Charts, tables, and filters were used to highlight key performance areas and allow users to monitor inventory status and customer order tracking efficiently. The completed dashboard acts as a practical tool to support better planning, faster decision-making, and improved coordination between departments.

3.0 RESULTS AND DISCUSSION

3.1 Dashboard Interface

The developed ASAP Tracker dashboard successfully consolidates critical warehouse data into a centralized, real-time interface. Refer to Figure 5, it presents key information such as ASAP Work Order (WO) numbers, FG article numbers, CRDs (Customer Required Dates), reservation status, stock status, reorder levels, stock levels, and calculated balance figures. The interface also includes interactive filters for WO number, reservation status, and stock status, allowing users to isolate specific data segments based on operational needs.

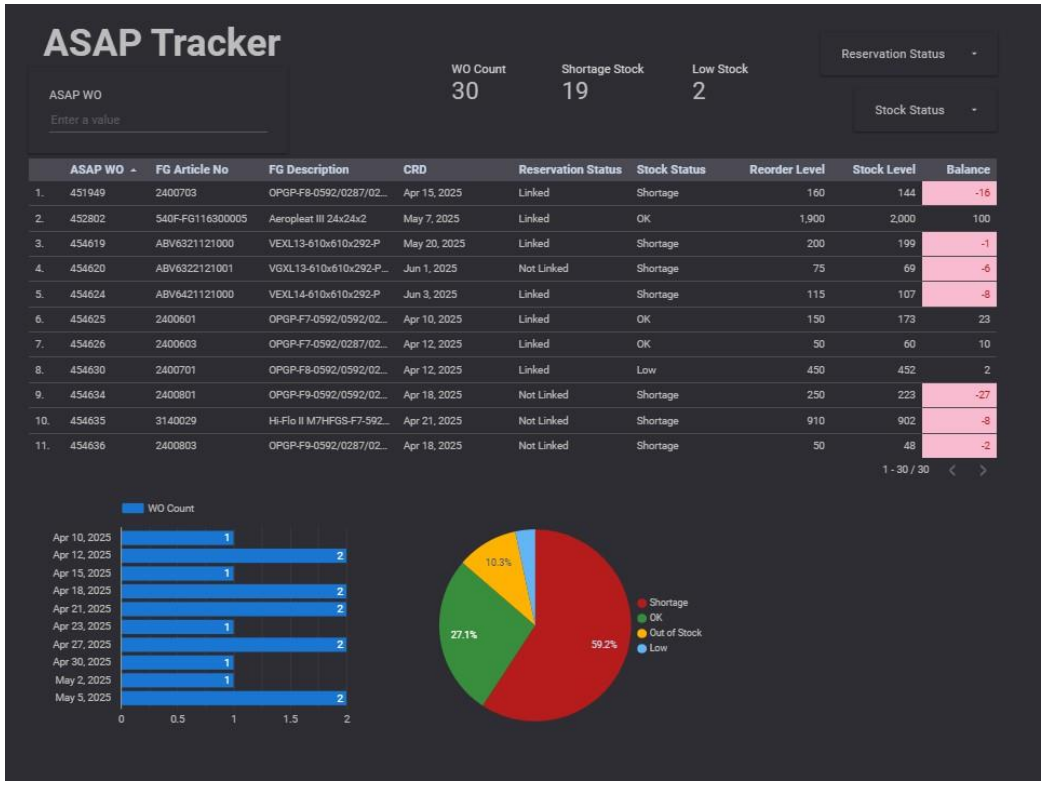

Figure 5: ASAP Tracker Dashboard Interface

From the dashboard, refer to Figure 6, a total of 30 Work Orders were tracked. Among them, 19 items are currently flagged as having stock shortages, and 2 items are marked under low stock conditions. Refer to Figure 7, the dashboard calculates the stock balance by comparing stock level against the reorder level, with negative balances clearly highlighted in red for quick identification of critical shortages.

Figure 6: KPI Scorecard

Figure 7: Stock level Against Reorder Level

The visual analytics section features a bar chart (Figure 8) representing WO count by date, allowing planners to observe daily trends in work order generation. Additionally, a pie chart (Figure 9) provides a visual breakdown of stock conditions: shortage (red), low stock (yellow),

and sufficient stock (green), giving users a quick overview of inventory health.

Figure 8: Bar Chart of Work Order Count by Date

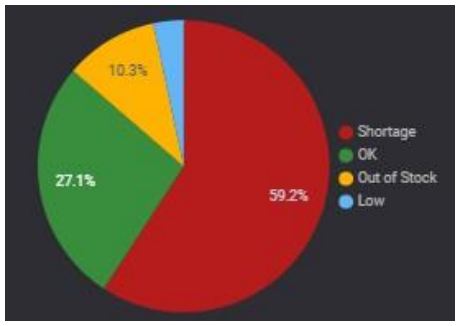

Figure 9: Pie Chart of Work Order Status

3.2 Flow Process: Using the ASAP Tracker Dashboard

Referring to Figure 10, to begin using the ASAP Tracker Dashboard, users first access the dashboard platform via Google Looker Studio using the appropriate link or system access. Once inside, users can optionally search for a specific ASAP Work Order (WO) number to focus on a particular order. To refine the data further, users may apply filters based on Reservation Status (e.g., Linked or Not Linked) or Stock Status (e.g., OK, Shortage, Low, Out of Stock). These filters help narrow down the data based on operational needs and priorities.

After setting the filters, users review the top summary indicators that display the total number of WOs being tracked, how many items are currently facing stock shortages, and how many are in a low stock condition. These quick stats offer an overview of current warehouse conditions.

The main data table provides detailed insights into each WO, including the FG article number and description, the Customer Required Date (CRD), the reservation status of each item, and the current stock condition. Users can compare the reorder level with the current stock level to determine the stock balance. Items with a negative balance are highlighted, indicating a shortage that may need urgent action.

Finally, users can refer to the visual charts for an overall understanding of trends. The bar chart shows how many WOs are created each day, while the pie chart displays the distribution of stock statuses. Based on these insights, planners or warehouse staff can take appropriate action by initiating replenishment processes, adjusting priorities, or coordinating with other departments for timely decision-making.

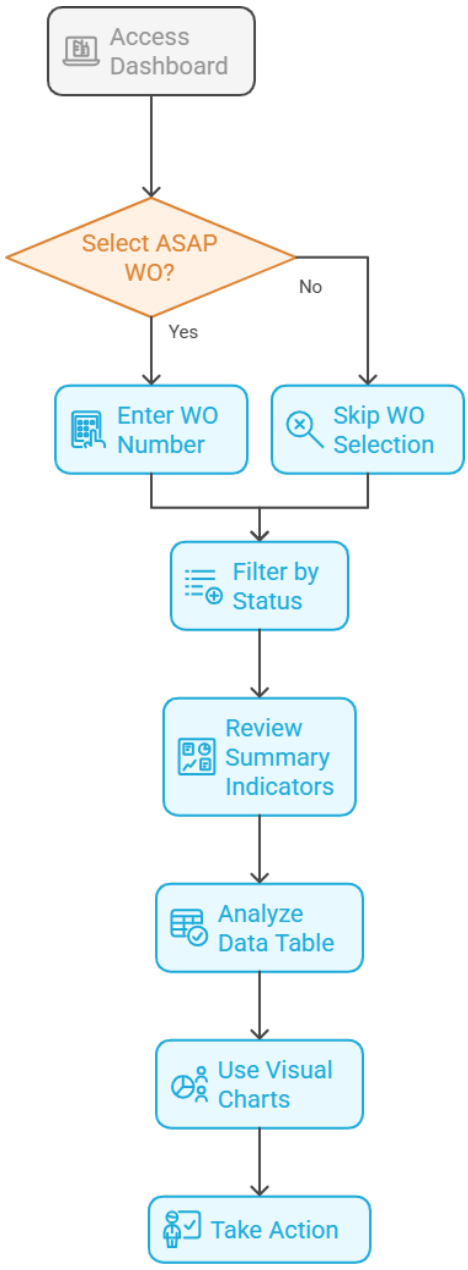

Figure 10: Flow Process to Use ASAP Tracker Dashboard

3.3 User Guide

The ASAP Tracker Dashboard is designed to be intuitive and user-friendly, ensuring that planners, warehouse personnel, and the CSG team can quickly access and interpret key warehouse data. Upon opening the dashboard in Google Looker Studio, users are presented with a real-time overview of ASAP Work Orders, stock conditions, and order tracking statuses.

To begin, users may utilize the ASAP WO search bar to locate specific work orders. This is useful when tracking the status of a particular customer order. Next, users can apply filters such as Reservation Status and Stock Status to narrow down the data according to their operational needs. For example, selecting “Shortage” under Stock Status will immediately display only items facing stock issues.

The summary section at the top displays the total number of Work Orders, how many are facing shortages, and how many are low in stock. These figures give users a quick snapshot of the warehouse's current performance.

The main data table lists detailed information including FG Article Numbers, CRDs, reservation links, reorder levels, stock levels, and stock balances. Negative balances, highlighted in red, help users quickly identify critical stock shortages.

Lastly, the bar and pie charts offer visual insights such as WO count by date and overall stock condition breakdown allowing for faster trend recognition. With this dashboard, users are empowered to monitor, analyze, and respond to stock conditions effectively, promoting improved warehouse planning and coordination.

4.0 CONCLUSION

This project was carried out with the primary aim of improving the efficiency of tracking customer orders, stock levels, and replenishment activities within the ASAP (ready stock) system at Camfil Batu Gajah's Finished Goods Warehouse. The current manual and fragmented tracking process posed significant challenges, such as lack of visibility, slow decision-making, and increased potential for miscommunication between the planning, warehouse, and CSG teams.

To address these issues, two main objectives were established: first, to identify key inefficiencies in the current process; and second, to develop a real-time centralized warehouse dashboard to enhance inventory tracking and warehouse performance. Using the Ishikawa diagram and process mapping, several inefficiencies were identified, particularly related to manual data handling and delayed information sharing. Based on these findings, a real-time dashboard was developed using Google Looker Studio, integrating essential data points such as Work Order numbers, FG article information, stock levels, reservation status, reorder levels, and CRDs.

The result was a functional, interactive dashboard that offers users a centralized view of real time warehouse operations. It includes summary metrics, detailed item-level data, and visualizations that support quick decision-making. The dashboard enhances visibility, reduces manual tracking efforts, and improves communication across departments. It also enables users to identify stock shortages, prioritize replenishments, and monitor daily work order trends effectively.

In conclusion, this project has met its key objectives and successfully delivered a practical tool that supports warehouse efficiency. While the dashboard currently focuses on tracking, future improvements could include automated alert systems, predictive inventory analytics, or integration with ERP systems for end-to-end visibility. These enhancements would further increase operational agility and responsiveness in managing customer demand.

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Development Of High-Efficiency Roller Trolley to Minimize Operator Movement in Workspaces

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ABSTRACT

This study focuses on the ergonomic and operational issues related to manual material handling at the Quality Gate Station of an automotive industry, where workers often have to lift heavy poly boxes exceeding 30 kg. The main aim is to create a high-efficiency roller trolley system that is intended to reduce unnecessary movement by operators, lessen physical strain, and improve workflow efficiency. The research utilizes a structured problem-solving approach that includes gathering data through questionnaires, employing Fishbone Diagram analysis for root cause analysis, and applying the Plan Do-Check-Act (PDCA) cycle for ongoing design refinement. Information collected from operator surveys indicated notable ergonomic issues, such as repetitive lifting and awkward positions contributing to musculoskeletal disorders. Utilizing Autodesk Inventor and CATIA software, the conceptual trolley design was created to assess ergonomic postures. The suggested trolley incorporates height-adjustable handles, low-friction wheels, and a scissor-lift mechanism designed to minimize bending and lifting strain. Ergonomic evaluations using REBA analysis, demonstrated a decrease in ergonomic risk scores and an increase in operator comfort. Although no physical model was constructed, the results suggest that the conceptual design could considerably enhance safety, lower fatigue, and boost productivity. The results offer a scalable model for future ergonomic advancements in industrial environments, highlighting the importance of simulation-based design and ongoing improvement methods.

Keywords: Ergonomic design, Roller trolley, Material handling, PDCA, REBA, Operator movement reduction.

1.0 INTRODUCTION

1.1 Literature review

This project intends to design and build an improved material handling system in the shape of a roller trolley, with the goal of addressing inefficiencies and ergonomic risks Quality Gate Station in an automotive industry. This station is crucial in ensuring that only high-quality components pass through the manufacturing process before distribution. Currently, operators manually lift and transfer heavy poly boxes during inspection, which causes delays and physical strain. Repetitive manual handling put workers at risk for musculoskeletal diseases (MSDs), weariness, and long-term problems such back pain and joint strain. To address these concerns, the suggested roller trolley will reduce the requirement for lifting and carrying, resulting in smoother, more ergonomic handling of inspection items.

Ergonomic design is critical in increasing the safety and productivity of material handling equipment. Poor ergonomic procedures are closely associated with an increase in occupational injuries, absenteeism, and reduced operational production (Anderson & Smith, 2019; Brown, 2020). Material handling equipment (MHE), such as roller trolleys, can dramatically reduce operator fatigue and biomechanical stress when fitted with height adjustable handles, shock-absorbing wheels, and lightweight frames (Chen & Lee, 2021; Foste & Martinez, 2020). Tools

such as the Rapid Entire Body Assessment (REBA) are used to assess ergonomic concerns, frequently highlighting repetitive and forceful movements as essential areas for improvement (Williams and Zhao, 2019). By correcting these ergonomic flaws, current MHE helps to create safer and more productive work environments.

The combination of modern mechanical technology and ergonomic innovation is becoming more common in industrial material handling. Karakuri mechanisms, for example, use gravity and mechanical motion instead of electricity to automate simple operations, resulting in increased energy efficiency and ergonomics (Kittidecha et al., 2024). Similarly, smart technologies like Automated Guided Vehicles (AGVs) and IoT-enabled carts improve task precision, eliminate manual labour, and encourage real-time monitoring to prevent system downtime (Nakamura & Roberts, 2022). This project builds on previous precedents by developing a roller trolley system to improve quality inspection at Burnmark Industries. The initiative emphasises the potential of ergonomic solutions to improve industrial practices, acting as a model for wider use in the manufacturing industry.

1.2 Problem Statement

Maintaining good product quality is critical in the automotive industry, and every component must be thoroughly tested before proceeding to the next step of production. The Quality Gate Station plays an important part in this process, although it faces major challenges. One important concern is the manual handling of heavy poly boxes, which operators must lift, move, and arrange repeatedly throughout inspections. This repetitious operation slows the inspection process, generates delays, and lowers overall efficiency. More significantly, it places a significant physical strain on workers, resulting in weariness, injuries, and an increased risk of musculoskeletal illnesses. These difficulties not only have an influence on worker health, but they also increase productivity and costs.

1.3 Objectives

Based on the problem statement, this project identifies three primary goals for enhancing process efficiency and operator ergonomics at the Quality Gate Station.

i. To identify unnecessary material handling and movement, leading to improved workflow efficiency.

ii. To design a roller trolley to reduce operator's movement in ergonomic aspect. iii. To analyze the effectiveness of the improvement made.

1.4 Scope and Limitations of Study

This project is about developing and building a roller trolley system for the Quality Gate Station in an automotive manufacturing setting. Rather of reorganising the entire manufacturing or inspection process, it seeks to improve ergonomics at the Quality Gate. The trolley is designed to help workers transport heavy poly boxes more safely and effectively, particularly in places with limited space and specific storage layouts. It helps with activities like carrying parts, eliminating physical lifting, and putting boxes at appropriate heights for inspection. Research indicates that ergonomic tools, such as trolleys, might reduce the incidence of musculoskeletal disorders (MSDs) by eliminating awkward motions and repeated jobs (Wurzelbacher et al., 2020). In automotive settings, ergonomic changes have been connected to increased worker safety and productivity (Baraldi & Kaminski, 2007). Furthermore, NIOSH guidelines emphasise the relevance of ergonomic solutions in decreasing physical strain and preventing work-related accidents.

2.0 METHODOLOGY

2.1 Root Cause Analysis Method

The Fishbone Diagram, also known as the Ishikawa Diagram or Cause-and-Effect Diagram, is a well-known root cause analysis tool that will be used in this study to systematically identify the underlying factors causing inefficiencies and productivity issues at the Quality Gate Station. This graphic tool makes it easier to organise and categorise the sources of an issue, improving analysis clarity and assisting in the development of specific solutions. In this study, the Fishbone Diagram will be used to investigate numerous variables influencing the design, functionality, and user experience of the proposed roller trolley system. This organised approach will help to enhance the design and improve operating efficiency.

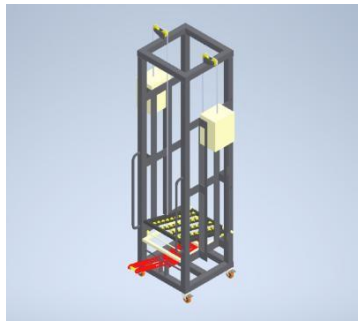
2.2 Problem Solving Method

The PDCA (Plan-Do-Check-Act) cycle is a systematic problem-solving process used in this study to create a high-efficiency roller trolley and assess its influence on productivity. This technique promotes continual improvement by allowing for incremental tweaks to solve inefficiencies in the current design. It is suitable for this research since it allows for continuous refinement depending on analysis and results.

2.3 Suggested Designs

The table below illustrates the potential roller trolley designs created to increase ergonomics and efficiency at the Quality Gate Station.

Table 1 Designs of Roller Trolley

Design 1	Design 2	Design 3
		

2.4 Observations Method

The research methodology used in this study was mostly qualitative, relying on direct observation, structured questionnaires, and ergonomic evaluation utilising the Rapid Entire Body evaluation (REBA) method. These approaches were used to systematically detect, assess, and quantify the physical demands and ergonomic dangers of manual material handling at the Quality Gate Station. Structured questionnaires were created and given to a specific group of operators involved in material handling. The questionnaires were created to collect self reported information about physical discomfort, perceived strain, task frequency, and the overall usefulness of present equipment. This instrument also requested subjective comments on the potential advantages and preferences for an enhanced tram system. The inclusion of operator feedback was critical to ensuring that the proposed design solutions met real-world user needs and experiences. In parallel, a REBA analysis was carried out to objectively evaluate the ergonomic risk factors in the current workflow. This method entailed

observing workers performing typical handling tasks and assessing their posture, movement, force exertion, and load characteristics. The REBA ratings were used to categorise the risk associated with these activities, identifying crucial areas that require ergonomic intervention. By combining operator feedback with rigorous ergonomic evaluation, this study provided a thorough understanding of the old system's limits and influenced the design requirements for the suggested roller trolley solution.

3.0 RESULTS AND DISCUSSION

There are 2 questionnaires given to the respondents which the first one is to evaluate the ergonomic aspects of roller trolley usage to develop a high-efficiency design that minimizes operator movements and enhances comfort, safety, and productivity. The collected feedback will help identify challenges, usability concerns, and potential improvements to optimize trolley design for various work environments. The second questionnaire is to collect the feedbacks of the respondents on the conceptual roller trolley design

3.1 Analysis of questionnaire data

3.1.1 Ergonomic Assessment for High-Efficiency Roller Trolley Development

Table 2 shows the data of the first questionnaire of 13 respondents.

Table 2 First questionnaire

Questions	Answers	Responses
How often do you lift or move heavy poly boxes during a work shift?	Constantly (more than 20 times per shift)	7 (53.8%)
How much does a typical poly box weigh when fully loaded?	10-20 kg	4 (30.8%)
Ergonomic Challenges & Discomfort		
Questions	**Answers**	**Responses**
On a scale of **1-5**, how much discomfort or pain do you experience when lifting poly boxes? *(1 = No discomfort, 5 = Severe pain)*	3 (Moderate discomfort)	6 (46.2%)
Which areas of your body experience the most strain when lifting poly boxes? (Select all that apply)	Lower back Shoulders	11 (84.6%) 11 (84.6%)
On a scale of **1-5**, how difficult is it to lift and move a fully loaded poly box? *(1 = Very easy, 5 = Extremely difficult)*	4 (Difficult)	6 (46.2%)
On a scale of **1-5**, how often do you need to bend, twist, or reach awkwardly while handling poly boxes? *(1 = Never, 5 = Constantly)*	4 (Important) 5 (Very important)	6 (46.2%)

Have you suffered any injuries related to lifting poly boxes in the past year?	Minor strain/discomfort	7 (53.8%)

Workplace Conditions & Equipment

Questions	Answers	Responses
On a scale of **1-5**, how suitable is your current work environment for lifting and moving polyboxes?	3 (Moderate)	5 (38.5%)
What type of surface do you work on when lifting polyboxes?	Smooth floor	4 (30.8%)
On a scale of **1-5**, how effective are the lifting aids or equipment available to assist you? *(1 = Not available, 5 = Very effective)*	3 (Moderate help)	5 (38.5%)
Would adjustable-height workstations or mechanical lifting aids improve your work efficiency and comfort?	4 (Very helpful) 5 (Extremely helpful)	6 (46.2%) 6 (46.2%)

Design and Safety Improvements

Questions	Answers	Responses
On a scale of **1-5**, how important is an **adjustable handle height** for improving comfort and usability?	4 (Important)	7 (53.8%)
What is your preferred handle design for better grip and comfort?	5 (Horizontal bar)	5 (38.5%)
On a scale of **1-5**, how important is it for the trolley to require **minimal effort to push or pull** when fully loaded? *(1 = Not important, 5 = Very important)*	4 (Important) 5 (Very important)	6 (46.2%) 6 (46.2%)
How stable should the upcoming roller trolley be when moving across different surfaces? *(1 = Not stable at all, 5 = Very stable)*	5 (Very stable)	7 (53.8%)
On a scale of **1-5**, how much would an **enhanced braking system** improve the safety of the trolley? *(1 = No improvement, 5 = Significant improvement)*	4 (Very helpful)	4 (61.5%)
What type of wheels would be most suitable for your work environment	Rubber wheels	9 (69.2%)

To identify the physical obstacles experienced during material handling at Burnmark Industries Sdn. Bhd.'s Quality Gate Station, 13 operators were given a standardised questionnaire. The responses revealed useful information about the frequency of manual handling jobs, physical strain, and desires for ergonomic changes. According to Table 2, a large percentage of responders (54%) reported lifting poly boxes more than 20 times every shift, with 23% handling boxes weighing more than 30 kg. The tasks caused significant physical discomfort, with an average reported pain level of 3.6 on a 5-point scale. The lower back, shoulders, and wrists were found as the most impacted locations. The questionnaire also indicated that 46% of operators had sustained moderate to severe lifting-related injuries in the previous year. Furthermore, most operators worked on surfaces like ramps or uneven floors, which increased ergonomic dangers. The complexity of tasks and the frequency of awkward postures were evaluated 3.6 and 4.3, respectively, indicating a high level of physical stress. Over 75% preferred adjustable-height platforms with mechanical lifting help. Angled handles were preferred to reduce wrist deviation and increase control.

3.1.2 Evaluation of Conceptual Roller Trolley Design

Table 3 shows the data of the second questionnaire of 13 respondents.

Table 3 Second questionnaire

Questions	Answers	Responses
Have you experienced discomfort or injury from manual lifting tasks?	Yes	9 (69.2%)
Have you been shown the design concept of the proposed roller trolley?	Yes	13 (100%)
How clearly do you understand how the proposed trolley is supposed to function?	Somewhat clearly	6 (46.2%)
Do you believe the design addresses the physical challenges of your current job (e.g., bending, lifting, reaching)?	5 (Strongly agree)	6 (46.2%)
The roller trolley would reduce lower back strain.	5 (Strongly agree)	6 (46.2%)
The height-adjustable feature is important and useful.	5 (Strongly agree)	6 (46.2%)
The handle design appears ergonomic and easy to grip.	4 (Agree)	6 (46.2%)
I would feel safer handling heavy boxes with this trolley.	5 (Strongly agree)	7 (53.8%)
It would reduce the need for two-person lifts.	5 (Strongly agree)	8 (61.5%)
Do you believe the trolley would make your inspection tasks faster?	5 (Strongly agree)	9 (69.2%)
How easy do you expect the trolley to maneuverer within the Quality Gate area?	Very easy Easy	5 (38.5%) 5 (38.5%)

Would the trolley help reduce the number of steps or movements you currently perform?	Yes	12 (92.3%)
How likely would you be to use this trolley if it was available?	5 (Strongly agree)	7 (53.8%)
Overall, how satisfied are you with the proposed design based on what has been shown to you?	Very satisfied	8 (61.5%)

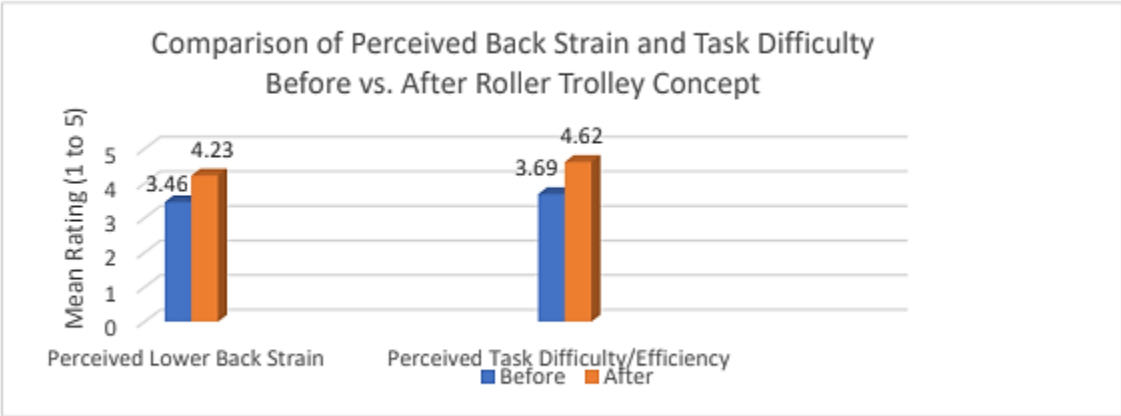


Figure 1 Before vs. After Roller Trolley concept

According to the survey, 69.2% of workers have experienced discomfort or injury as a result of physical lifting, underscoring the need for a more ergonomic option, such as the proposed roller trolley. While all participants had seen the trolley design, over half (46.2%) only "somewhat clearly" understood how it functioned, indicating that more explanation may be required. Almost half strongly agreed that the trolley would relieve physical strain and lower back pain. Positive feedback was given to key elements including the height-adjustable platform and ergonomic grip, with 46.2% strongly agreeing on their utility and simplicity of use. Safety and efficiency were also mentioned, with more than half feeling safer using the trolley, 61.5% saying it would replace two-person lifts, and 69.2% believing it would speed up inspections. Furthermore, 77% found it easy to operate in minimal settings, and the majority expressed strong acceptance, with 53.8% wanting to use it and 61.5% extremely delighted with the design.

3.2 Comparison of material handling between current practice and proposed trolley

The comparison of material handling between current practice and proposed trolley is shown in Table 3.

Table 3 Current Practice vs. Material handling using proposed trolley

Current Practice	Material handling using proposed trolley
 • Two operators bend their knees and waists to lift a huge poly package from a low rack.	 • One operator utilises the trolley to transport the poly box without bending.
• Lifting and movement require the cooperation of two individuals.	• Trolley's wheels enable for easy mobility without lifting. • Operator maintains upright stance.
 • Two operators stretch over shoulder height to lift a poly package from the top shelf. • High lifting increases the risk of dropping the package.	 • To lift the box, the operator employs the trolley's lever lift system. • The operator maintains a neutral, upright position. • Mechanical support is provided for vertical movement by the trolley.

3.3 Comparison of REBA Analysis between current practice and the proposed trolley design

Table 3 shows the comparison of REBA Analysis between current practice and the proposed trolley design.

Table 3 REBA Analysis Current Practice vs. Proposed Roller Trolley Design

REBA Analysis Criteria	Current Practice	Proposed Roller Trolley Design
REBA Score	14-15 (Very high risk)	3 (Low risk)
Postural Risk	High - trunk flexion, overhead reaching, and difficult lifting.	Low – neutral postures maintained during operations
Load Handling	High physical effort	Minimal
Trunk position	Significant forward bending	Upright posture maintained via scissor-lift mechanism
Shoulder & Arm Use	Repeated overhead reaching, poor arm posture	Neutral arm and wrist posture due to ergonomic handle design
Wrist Position	Strain from awkward gripping	Neutral wrist posture during push/pull
Repetition & Force	Frequent lifting, pushing with high resistance	Smooth movement with low-resistance wheels
Biomechanical Load (Back, Shoulders, Wrists)	High – major stress on back, shoulder, wrists	Reduced – ergonomic design lessens strain on key areas
Fatigue Potential	High – due to repetitive physical tasks	Low – design promotes efficient, low – strain operation
Postural variation & Mobility	Limited – repetitive awkward motions	Improved – better posture and less repetition
Risk Level (per REBA scale)	Very high – immediate investigation and change required	Low – change may be needed, monitor for improvement

The REBA (Rapid Entire Body Assessment) analysis shows that the suggested roller trolley greatly improves ergonomic safety over conventional manual handling methods. The current tasks, which required frequent lifting, bending, and reaching, yielded high REBA scores of 14-15, indicating a high risk of musculoskeletal problems, particularly in the lower back, shoulders, and wrists. In comparison, the roller trolley design had a significantly lower REBA score of 3, owing to features such as an adjustable scissor-lift platform, low-friction wheels and

ergonomic handles that accommodate neutral arm positions. These findings are consistent with earlier research highlighting the importance of ergonomic tools in lowering MSD risks during material handling duties (Sari & Yusmita, 2022; Ahmad et al., 2021). While the results are based on simulations, they indicate that the roller trolley is a promising solution that requires additional confirmation through real-world testing.

4.0 CONCLUSION

This study looked into the ergonomic and operational issues of manual material handling at Burnmark Industries Sdn. Bhd.'s Quality Gate Station, where workers were subjected to substantial physical strain when carrying heavy poly boxes. In response, a high-efficiency roller trolley system was created, which included ergonomic elements such as a height adjustable lift, roller-assisted surfaces and low-friction wheels. Questionnaire results and REBA analysis indicated that present procedures caused significant dangers, whereas the new design promised to minimise strain, improve safety, and increase efficiency. Overall, the study demonstrates that ergonomic solutions such as the roller trolley can improve worker well-being and foster a more sustainable, human-centred workplace environment.

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Development of Standard Operating Procedures (SOP) for the Safe Operation of the Slicer Machine for Smoked Duck Breast

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ABSTRACT

This study aims to develop a Standard Operating Procedure (SOP) to enhance the safety and efficiency of slicing machine operations in the processing of smoked duck breast at a company specializing in the manufacturing and supply of Pau and Dim Sum products. The absence of a formal SOP has increased safety risks, particularly among new or untrained workers, due to the machine's extremely sharp blades and high operating speed. A previous incident involving a similar machine the Siew Mai machine, a semi-automated device used in Dim Sum preparation resulted in several serious injuries due to the lack of SOPs and safety guards. Between 2020 and 2023, the company recorded four major injury cases involving the Siew Mai machine. The main objectives of this study are to identify potential hazards related to the slicing machine, analyse the risks arising from the lack of SOPs, and evaluate the effectiveness of the newly developed SOP. The research adopted a qualitative approach, including direct workplace observations, structured interviews with machine operators and supervisors, and surveys among production staff. Root cause analysis using the "5 Whys" technique revealed organizational weaknesses in prioritizing machine-specific SOP development. Findings show that the absence of SOPs significantly contributed to unsafe working practices. Before the SOP was introduced, the weekly potential injury rate was recorded at 64.3%, with low levels of understanding regarding safe machine handling. After implementation, safety awareness increased to 95%, while the potential for injury decrease to just 7.1%. Although no previous accidents have been recorded involving the slicing machine, the newly developed SOP has successfully standardized operating procedures, enhanced training effectiveness, and reduced the likelihood of workplace injuries. Overall, this project highlights the critical importance of implementing SOPs for high-risk food processing equipment and offers a practical solution to improving worker protection and operational performance within a manufacturing environment.

Keywords: Standard Operating Procedure, Slicer Machine, Risk Reduction, Workplace Safety

1.0 INTRODUCTION

The food processing industry is one of the sectors that places a high priority on worker safety, product quality, and operational efficiency. In environments where high-speed machinery with sharp components is routinely operated, the risk of occupational injuries must be addressed proactively. Backstrom and Doos (2000) report problems related to safety devices from 76 accidents in automated production obtained from 21 work sites in Swedish manufacturing industry over a two years period (1988–1990). The study reveals that a production installation should not be regarded as safe simply because it possesses safeguards. The latter include barriers, interlocks, hold to run control, two hand controls and presence sensing device. The study identifies four levels of problems namely no or low level of safeguarding, non-use of safeguards (remove, circumvent, defeat, decouple), failure of safeguards to stop all machine movements in the danger zone (residual energy, inertia).

In another study, 592 lockout/tagout related incidents in the US resulting in a total of 624 fatalities were reviewed (Bulzacchelli et al., 2008). In the majority of cases, 70% lockout

procedures were not attempted at all. There were very few incidents in which a lockout attempt was made and a fatality occurred due to human error (5.2%) or mechanical failure (1.2%). The author recommends further research on understanding barriers to following lockout/tagout procedures and finding ways to increase usage of these procedures. Thus, some researchers suggest of implementing Standard Operating Procedure (SOP) (Cruz et al., 2006).

SOP are written procedures developed and implemented in a facility to prevent direct contamination or adulteration of the products. The facility is required to maintain these written procedures on file, and these must be available to regulating or government bodies upon request. SOP include a complete description of the specific activities required to maintain utensils and equipment free of pathogenic microorganisms and minimal deteriorating microbiota, preventing the contamination of foodstuffs that get in contact with these utensils and equipment (Cruz et al., 2006).

Observations conducted in the production area of Company A revealed a critical gap in internal operational safety, specifically, the absence of a Standard Operating Procedure (SOP) for the slicer machine used in the preparation of smoked duck breast. Although no formal incidents have been attributed to this equipment to date, the potential hazard posed by its sharp blades and rapid movements remains significant, particularly for new or inexperienced operators. (Chinniah et al., 2018) aimed to investigate the flaws in six different risk estimation tools applied to the four production activity situations.

In the absence of a documented SOP, the likelihood of human error, inconsistent operational procedures, and unsafe handling practices increases, thereby elevating the risk of workplace accidents. A relevant precedent within Company A involves the Siew Mai machine, which was previously operated without adequate machine guarding or a formal SOP. This oversight contributed to a series of injury incidents during machine use, underscoring the critical role of clear procedural guidelines in ensuring workplace safety. (Scorgie et al., 2024), optimising worker training programmes through the use of innovative methodologies such as virtual reality could contribute to improving safety. Hygienic status of food production lines and to verify the effectiveness of cleaning procedures Chen and Godwin (2006).

Given the operational similarities between the slicer and the Siew Mai machines, both of which demand precision, caution, and heightened safety awareness, the documented injuries associated with the latter highlight the urgent need for a formal SOP for the former. Accordingly, this study aims to develop a comprehensive and practical SOP for the slicer machine used in smoked duck breast production. The proposed SOP is designed to standardize safe operational practices, reduce the risk of occupational injuries, and enhance overall efficiency on the production line. In doing so, this initiative addresses a significant gap in the current safety framework and contributes to the development of a safer, more professional working environment within Company A.

2.0 METHODOLOGY

This section outlines the research methodology employed to systematically develop a Standard Operating Procedure (SOP) for the slicer machine used in the processing of smoked duck breast at Company A. A structured and methodical approach was adopted to address the research objectives effectively. The methodology encompasses the overall research strategy, design framework, data collection methods, research instruments, and analytical techniques utilized throughout the study. Each component of the methodology was carefully selected to ensure a thorough investigation of the existing operational practices and to support the

formulation of an evidence-based SOP. This methodological framework serves as a comprehensive guide for assessing and implementing the proposed SOP, with the ultimate goal of enhancing process consistency, operational efficiency, and workplace safety in the slicing operations at Company A. Figure 1 shows the process flow for system development of SOP.

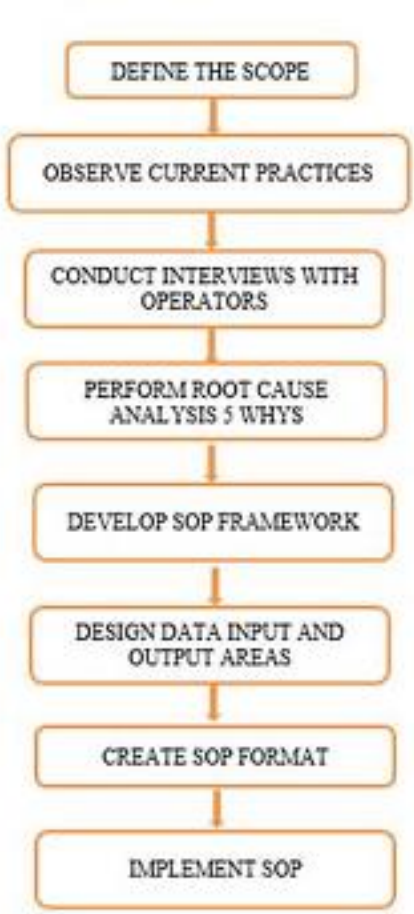

Figure 1: Process flow for system development of SOP

2.1 Research Design

This study adopts a fully qualitative research design, prioritizing in-depth understanding and contextual analysis over quantitative measurement. By conducting open-ended interviews and discussions with key stakeholders, the research aims to explore the underlying challenges and potential opportunities associated with the development of a Standard Operating Procedure (SOP) for the slicer machine used in smoked duck breast processing at Company A. Qualitative inquiry is particularly well-suited for examining complex operational and behavioural phenomena, as it facilitates a holistic understanding of participants' experiences, perceptions, and workplace practices .paragraph that follows.

2.1.2 Why Analysis

Figure 2 presents the 5 Whys analysis, which identifies the root causes underlying the absence of a Standard Operating Procedure (SOP) for the slicer machine used in the processing of smoked duck breast. This analytical tool is employed to systematically trace the foundational organisational and operational barriers that have impeded the development of formal safety protocols.

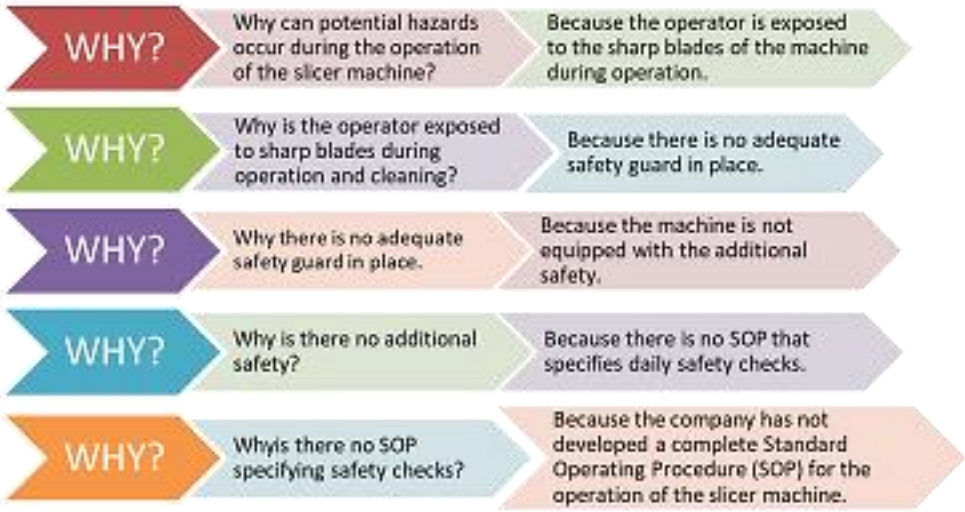

Figure 2: 5 Why Analysis identifies the root causes underlying the absence of a Standard Operating Procedure (SOP) for the slicer machine

2.2 Data Collection Method

2.2.1 Interviews

In-depth interviews with 12 slicer machine smoked duck workers, and 10 operations professionals provide qualitative insights into the complexities of everyday processes and communication issues.

2.2.2 Surveys

Structured surveys has been issued to 12 personnel in the slicer machine, production, and operations department to gather quantitative data on current communication techniques, task management, and general satisfaction.

2.2.3 Pilot Study

A pilot study was conducted prior to the full implementation of the Standard Operating Procedure (SOP) to evaluate the clarity, effectiveness, and suitability of the research instruments as well as the structure of the developed SOP. This initial phase aimed to identify any potential issues within the questionnaire, interview guidelines, or the SOP format that could affect the data collection process or user understanding during actual implementation. The pilot study involved 20 production operators and representatives who are directly involved in operating the slicing machine at Company A. Participants were selected based on varying levels of experience to ensure that the feedback obtained reflected perspectives from both new and experienced users. Throughout the pilot study, participants were asked to complete a questionnaire and take part in semi-structured interview sessions.

3.0 RESULTS AND DISCUSSION

A detailed analysis is presented focusing on both qualitative and quantitative data collected throughout the development and implementation of the Standard Operating Procedure (SOP) for the smoked duck breast slicing machine at Company A. Table 1 presents survey responses comparing employee feedback before and after the implementation of a SOP for the slicer machine. The table presents a comparative analysis of employee responses regarding

operational practices before and after the implementation of the Standard Operating Procedure (SOP) for the slicer machine at Company A. The data are categorized into two response groups: "Agree" and "Disagree."

Prior to SOP implementation, a significant proportion of respondents (64.3%) expressed disagreement with the safety or procedural effectiveness, while only 28.6% agreed. However, following the introduction of the SOP, there was a marked shift in perception: the level of agreement rose sharply to 95%, while disagreement dropped to just 7.1%.

This clear transition underscores the positive impact of implementing the SOP, highlighting its role in enhancing employee confidence, promoting safer operational practices, and improving procedural clarity in the workplace. These findings validate the importance of structured guidelines in mitigating risks and supporting operational consistency in food processing environments.

Table 1: Result of Potential Risk Before SOP Implementation growth

Response Category	Before use SOP	After use SOP
Disagree	64.3%	7.1%
Agree	28.6%	95%

Figure 3 show the results of a survey conducted among 14 operators, indicating that before the implementation of the SOP, only 28.6% agreed they were aware of the risks associated with placing their hands too close to the machine blade during operation, while 64.3% disagreed.

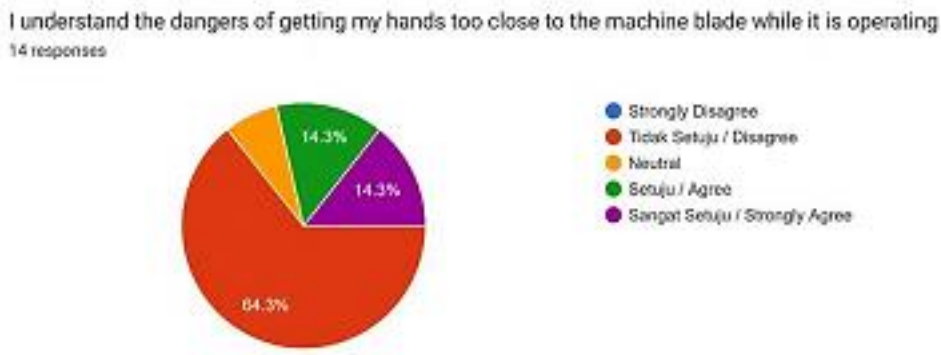

Figure 3: Total potential risk getting hands close the blade before use SOP

Figure 4 show the findings results clearly the SOP significantly enhanced operational consistency and safety awareness. After SOP training, nearly all operators reported better understanding and confidence.

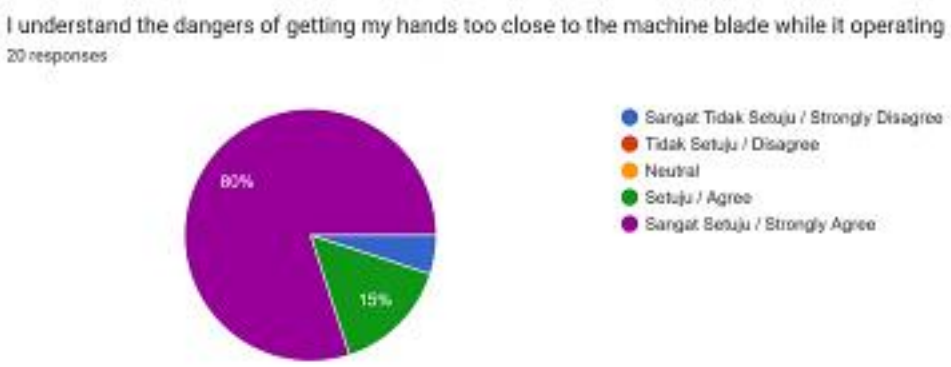

Figure 4: Total potential risk getting hand close after use SOP

4.0 CONCLUSION

This study has presented a comprehensive assessment of the development and implementation of a Standard Operating Procedure (SOP) for the slicer machine used in smoked duck breast processing at Company A. Employing a qualitative research methodology encompassing interviews, direct observations, and employee surveys the investigation has yielded critical insights into the role of SOPs in improving workplace safety, operational uniformity, and workforce performance.

The findings clearly indicate that the introduction of the SOP led to a substantial improvement in safety awareness among employees. Specifically, perceived risk of injury decreased from 64.3% to 7.1%, while understanding of safe operating procedures increased to 95% following structured training sessions. These outcomes underscore the SOP's effectiveness in reducing operational hazards and promoting safe machine handling.

Moreover, the SOP proved instrumental in standardizing complex machine operations, particularly in tasks associated with elevated risk. By offering clear, step-by-step guidance supplemented by visual aids, the SOP enhanced employee competence, particularly among foreign or inexperienced workers. Supervisors also observed a reduction in the need for constant oversight, indicating improved worker autonomy and a more streamlined production process. Overall, the successful implementation of the SOP illustrates its value as a practical intervention for fostering a safer and more efficient workplace.

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Enhancing Non-PO Procurement Efficiency through a Structured DMAIC Framework

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ABSTRACT

In today's fast-paced and technology-driven environment, organizations are under increasing pressure to enhance operational efficiency, reduce processing errors, and improve transparency in procurement activities. Traditionally, many manufacturing companies manage Non-Purchase Order (Non-PO) transactions using manual methods, including paper forms, physical approvals, and email-based communication. These outdated practices often result in slow processing, limited visibility, and a higher risk of human error. This study focuses on transforming the manual Non-PO and claim process into a fully digital workflow for non- registered suppliers at Company ABC. The project adopts the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to identify inefficiencies, analyze root causes, and implement a streamlined digital system. Key improvements include automated Purchase Requisition (PR) submission, real-time approval by the Head of Department (HOD), and integrated digital claim processing. The implementation of digital procurement system led to a process cycle time reduction of approximately 98.26%. The new system not only minimizes delays and manual errors but also significantly enhances process transparency, strengthens compliance, and represents a substantial advancement in procurement efficiency.

Keywords: DMAIC, Non-Purchase Order, Digital Procurement, Procurement Efficiency

1.0 INTRODUCTION

1.1 Background of study

In today's rapidly evolving business landscape, organizations are increasingly leveraging digital technologies to boost operational efficiency and sustain their competitive advantage. Procurement, particularly the management of purchases order and claims, stands out as an area that can greatly benefit from digital transformation (Karttunen et al., 2023) . These procedures have historically relied on manual systems, which have a significant risk of human mistake, are prone to delays, and offer limited transparency. Reliance on paper records, manual approval processes, and fragmented workflows frequently leads to inefficiencies that have a detrimental effect on financial operations and compliance standards in addition to slowing down procurement cycles (Joseph Ozigi Basiru et al., 2023)

Manual non-purchase order (non-PO) purchasing and claim processes often suffer from fragmented workflows, reliance on paper-based documentation, and manual approval steps, which lead to inefficiencies such as process delays and increased risk of errors. Procurement professionals often spend a significant amount of time on repetitive administrative tasks, with automation reducing manual workloads by up to 40%, thereby freeing valuable time and minimizing errors that cause delays across organizations (Althabatah et al., 2023). Therefore, digital transformation efforts in purchasing and supply management seek to address these challenges by renewing data infrastructure and automating processes to improve efficiency and accuracy (Karttunen et al., 2023).

At company ABC, the manual handling of purchase orders and claims introduces significant inefficiencies that hinder procurement effectiveness. A primary challenge is the dependence on physical signatures for hardcopy purchase requisitions, which often creates bottlenecks when documents are lost or signatories are unavailable, delaying approvals and subsequent procurement activities. Additionally, the physical transfer of documents across multiple departments extends the procurement cycle, as each stage requires manual intervention, increasing the risk of document loss, duplication, or misfiling. The absence of automation also means there is no real-time visibility into the status of purchase orders or claims, leaving requestors uninformed and reducing accountability. Manual processes are further burdened by repetitive data entry tasks that consume valuable employee time and are prone to human error, which can cause discrepancies and delays in order fulfilment. The absence of a centralized system results in poor communication and coordination, often leading to confusion, missed deadlines, and compliance issues. Moreover, manual procurement workflows depend heavily on email chains and physical document exchanges, which are cumbersome and inefficient, especially as business volumes grow. These challenges contribute to increased organizational expenses and slow approval cycles, ultimately affecting supplier relationships and cash flow management.

The current manual purchase order (PO) process also presents several inefficiencies and bottlenecks that hinder operational efficiency. Requestors are required to submit hardcopy purchase requisitions (PRs) to claim purchased items, leading to time-consuming processes and increased likelihood of errors or document misplacement. This manual approach often results in delays, especially when urgent purchases are made without following the standard procedure of obtaining prior approval from the Head of Department (HOD), leading to unauthorized spending and budgetary discrepancies. Furthermore, the approval process is hindered by the necessity of obtaining physical signatures from HODs, which can be time-consuming, particularly if the approver is unavailable. Additionally, the lack of a digital tracking system means that users have no real-time visibility into the status of their requests, leading to uncertainty and potential miscommunication. Hence, this research seeks to systematically improve the efficiency and reliability of the manual Non- Purchase Order (Non-PO) procurement process at Company ABC by employing the DMAIC methodology—comprising the phases of Define, Measure, Analyze, Improve, and Control. Through this structured approach, the study aims to identify root causes of existing inefficiencies, reduce approval delays, enhance process transparency, and ultimately develop a digital procurement system that streamlines operations and supports long-term organizational performance.

2.0 METHODOLOGY

Based on Figure 2.1, this study utilizes the DMAIC methodology Define, Measure, Analyze, Improve, and Control as a structured, data-driven framework commonly used in Lean Six Sigma to enhance business process performance (Monday, 2022) . Applied to Company ABC's manual Non-PO procurement process, DMAIC enabled a step-by-step approach to identifying inefficiencies, analyzing their root causes, and implementing targeted digital solutions. The method facilitated the transformation from a paper-based workflow to a streamlined digital system. Each phase of DMAIC contributed to improving accuracy, reducing delays, and ensuring process control, ultimately supporting sustainable operational improvements aligned with the organization's long-term efficiency goals.

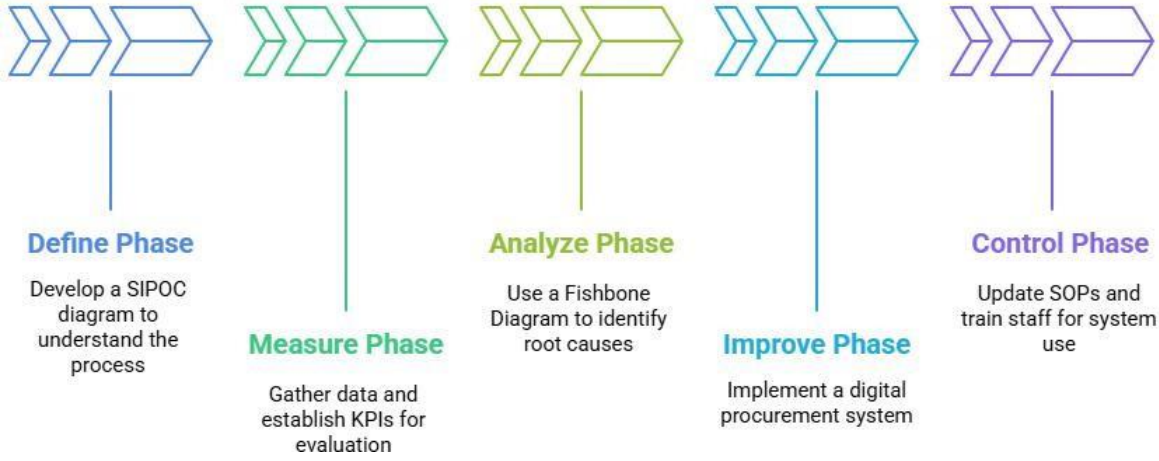

Figure 2.1: DMAIC Framework for Non-PO Procurement Improvement

2.0 Define Phase

To gain a comprehensive understanding of the existing Non-PO procurement workflow, a flow process diagram was developed during the Define phase of the DMAIC framework. This visual representation mapped out the entire procurement sequence, highlighting key stakeholders (such as employees, vendors, and department heads), critical documents (including PR forms and claims), and each major process step from submission and approval to claim verification and final purchase completion. The flow process diagram provided a clear and structured view of the operational steps and stakeholder interactions, helping to define process boundaries and clarify roles. This facilitated alignment in project scope and objectives, while also serving as a baseline for identifying bottlenecks and inefficiencies in subsequent phases. Ultimately, the flow process diagram became a vital reference for developing targeted, data-driven improvement strategies (Mussehl et al., 2022).

2.1 Measure Phase

Quantitative data were systematically gathered from historical procurement records and semi-structured interviews with key personnel involved in the Non-PO procurement cycle. This data collection aimed to identify critical metrics including average cycle time for approvals, the frequency of document resubmissions due to errors, and the occurrence of delays at specific process checkpoints. These insights enabled the definition of Key Performance Indicators (KPIs) such as turnaround time, error rate, and process adherence, which served as essential benchmarks for evaluating the impact of proposed improvements. The use of KPIs is vital in Lean Six Sigma projects, as it provides measurable targets to assess current state performance and track post-implementation outcomes (Srijithesh et al., 2025) . Establishing these indicators ensured that any process changes could be quantitatively assessed, thereby enhancing the validity and accountability of the improvement initiative.

2.3 Analyze Phase

To systematically uncover the underlying causes of inefficiencies within the Non-PO procurement process, the Fishbone Diagram also known as the Ishikawa Diagram was utilized as a structured root cause analysis tool. This method is particularly effective in visualizing cause-and-effect relationships and categorizing potential sources of variation across multiple dimensions such as People, Process, Technology, Materials, and Environment (Holifahtus Sakdiyah et al., 2022).

2.1 Improve Phase

Following the root cause analysis, a tailored digital procurement system was conceptualized and developed to directly address the inefficiencies identified in the manual Non-PO workflow. The solution was designed with several key features aimed at enhancing process speed, accuracy, and transparency. These included digital Purchase Requisition (PR) submission forms with built-in validation to reduce data entry errors, automated approval routing based on predefined hierarchies or cost centres, and real-time tracking dashboards that allowed users to monitor the status of their requests at any stage of the process. A pilot implementation was conducted in selected departments to evaluate system functionality, user experience, and integration with existing processes. Feedback from this pilot phase was used to refine the system before full-scale rollout, ensuring that it met user requirements and organizational standards. This phase was critical for validating the feasibility of the solution and for building user confidence in the digital transformation initiative.

2.2 Control Phase

To maintain the improvements made, the Standard Operating Procedures (SOPs) were updated to match the new digital system. Staff involved in the process were given proper training to ensure they understood how to use the system effectively.

3.0 RESULT AND DISCUSSION

3.1 Non-PO Flow process in Define Phase

Figure 3.1 presents the existing workflow for the Non-Purchase Order (Non-PO) procurement process. The process begins when the requester manually completes a Purchase Requisition (PR) form, typically sourced from an Excel template. After filling in the required details, the PR must be printed, signed, and physically submitted to obtain manual approval from the Head of Department (HOD). This step often introduces delays typically ranging from one to two days—due to the unavailability of the approver or other administrative constraints. Such delays contribute to process inefficiencies, miscommunication, and extended cycle times. Following HOD approval, the signed PR is forwarded in hardcopy to the Purchasing Department. At this stage, the department manually emails the supplier to initiate the invoicing process. Once the supplier responds, the requester may proceed with the purchase and later submit a claim to the Finance Department. The final stage involves manually filing the hardcopy documents for audit or forecasting purposes. However, this paper-based approach increases the risk of document loss, misfiling, and difficulties in retrieval, thereby compromising record-keeping integrity and compliance (Farotimi et al., 2023).

The current Non-PO procurement process begins with the requester manually filling out a Purchase Requisition (PR) form retrieved from an Excel file. The form is printed and submitted in hardcopy for manual approval by the Head of Department (HOD), often causing delays due to unavailability. Once approved, the form is sent to the Purchasing Department, which manually emails the supplier for invoicing. After supplier acknowledgment, the requester proceeds with the purchase and submits a claim to the Finance Department. Finally, all documents are filed manually, increasing the risk of loss or misplacement and reducing process efficiency.

Figure 3.1: Current Process Non-PO Purchase

3.2 Measure Phase: HOD Approval Delay Metrics

To quantify baseline performance and identify time-based inefficiencies in the Non-PO procurement process, specific attention was given to delays occurring at the Head of Department (HOD) approval stage. Approval delay is defined as the number of pending requests that exceeded the standard response time due to the unavailability or inaction of the designated approver.

Table 3.1: Monthly HOD Approval Delays (Jan–Mar)

Month	Number of Delayed HOD Approvals
January	16
February	15
March	22

The recorded number of delayed approvals attributed to the HOD stage 16 in January, 15 in February, and 22 in March demonstrates a consistent and significant operational challenge in the manual Non-PO procurement process (Table 3.1). These delays reflect systemic bottlenecks at the managerial level, where the approval of purchase requisitions depends on the physical availability and responsiveness of designated department heads. The increasing trend, especially the notable rise in March, suggests that the problem is not only persistent but potentially exacerbated by workload surges, absenteeism, or the absence of standardized escalation protocols. Such delays have a direct and detrimental effect on the overall procurement cycle time. When approvals are stalled, downstream processes such as

purchasing, invoicing, and payment disbursement are also delayed, leading to operational inefficiencies, missed procurement timelines, and potential strain in supplier relationships. Additionally, users experience frustration due to the lack of visibility and uncertainty about request status, which negatively impacts satisfaction and trust in the system.

These findings underscore the urgency of redesigning the approval workflow within a digital procurement system. Automation features such as scheduled reminders, auto-escalation to alternate approvers, and mobile-friendly approval interfaces can significantly reduce dependency on manual interventions. Moreover, real-time dashboards and notification mechanisms will allow stakeholders to track approval progress, thereby increasing accountability and responsiveness (Gami et al., 2024) . Addressing these delays through smart workflow automation will not only optimize processing speed but also contribute to more agile, transparent, and user-centric procurement operations.

3.3 Analyze Phase: Root Cause Identification Using the Fishbone Diagram

To systematically diagnose inefficiencies in the manual Non-Purchase Order (Non-PO) procurement workflow, a Fishbone Diagram was utilized to structure potential root causes across six key dimensions: Measurement, Machine, People, Material, Environment, and Management as shown in Figure 3.2. This approach provided a comprehensive framework for isolating process breakdowns and identifying areas requiring targeted intervention.

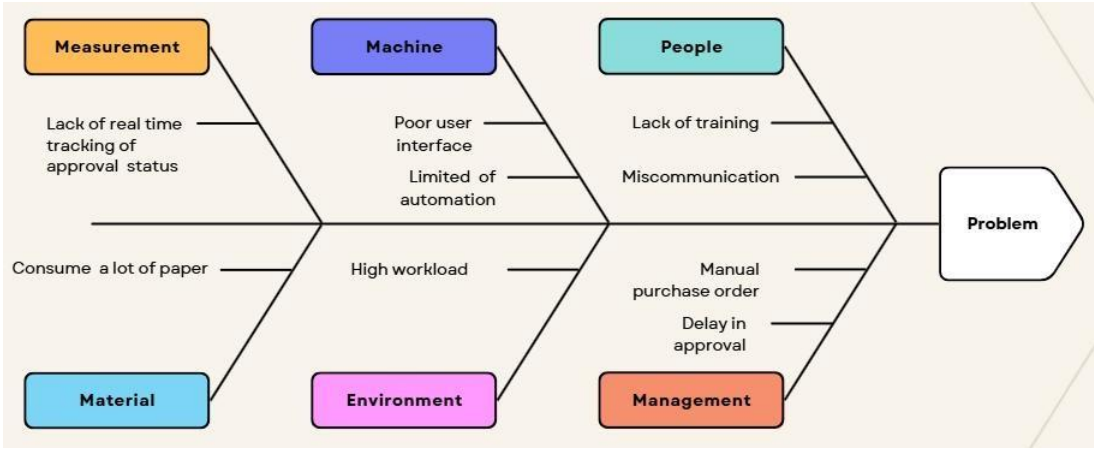

Figure 3.2: Root Cause Identification Using the Fishbone Diagram

Measurement deficiencies, particularly in manual Non-PO procurement systems, severely undermine the organization's ability to monitor and control process performance effectively. The absence of integrated digital monitoring tools means there is no mechanism to capture and present key process indicators such as cycle time, approval duration, rejection rates, or the volume of pending requests. As a result, stakeholders operate with limited visibility, relying instead on informal updates or verbal communication to track the status of transactions. This lack of real-time insight causes frequent follow-ups and unnecessary administrative effort, contributing to delays and inefficiencies. Moreover, the absence of structured data makes it difficult to evaluate historical trends or pinpoint recurring issues. For example, if certain departments consistently experience approval bottlenecks or document rejections, such patterns remain undetected due to the lack of traceable metrics. This data gap prevents managers from conducting accurate performance reviews or initiating targeted interventions.

Machine-related limitations in the current Non-PO procurement process significantly impact operational efficiency and user satisfaction. One of the primary issues lies in the lack of user-centric interface design. Existing systems are unintuitive and cumbersome, leading to confusion, longer task completion times, and frequent user errors. Routine activities such as approval routing, notification dispatch, and request status updates are still conducted manually, which introduces unnecessary delays and increases the risk of inconsistent or incomplete data. Moreover, the system lacks automation features that could otherwise streamline repetitive tasks and free up staff to focus on higher-value activities. Poor system integration across departments further compounds these issues by causing duplicated data entry and process fragmentation (Siddiqui et al., 2023)

People-related challenges stem from a lack of structured training, inconsistent understanding of SOPs, and fragmented communication channels. These gaps contribute to procedural errors, document mismanagement, and approval backlogs. Interdepartmental communication breakdowns, often due to reliance on informal email threads, further exacerbate cycle time inefficiencies. Studies have shown that digital literacy and collaborative workflows are essential to improving user adherence and minimizing operational misalignment (Brommeyer et al., 2024; Karttunen et al., 2023).

Material-related inefficiencies in the Non-PO procurement process largely stem from the heavy reliance on physical documents. Printed PR forms require multiple manual steps including printing, signing, scanning, and transporting which not only consume time but also increase the risk of document loss, misfiling, or damage. This reliance on hardcopy formats limits traceability and poses challenges for audits, especially when retrieval is needed across departments or locations. In high-volume or hybrid work environments, such manual handling is inefficient and unsustainable and transitioning to digital document management enhances process efficiency, security, and compliance readiness (Brueren & Dinger, 2025).

Environment factors such as high administrative workload and unbalanced task distribution reduce overall process throughput. In manual systems, repetitive data entry and approval handling create cognitive overload, increasing human error rates and lowering decision-making accuracy. A pressurized work environment with limited automation inhibits proactive behavior and delays responses to pending requisitions. Digital task support systems have been shown to mitigate fatigue and improve processing consistency (Argyle et al., 2021).

Management deficiencies present a fundamental constraint to the efficiency and modernization of the Non-PO procurement process. One of the most significant issues is the persistent reliance on manual authorization procedures, particularly the requirement for physical Head of Department (HOD) signatures, which introduces delays and disrupts workflow continuity. This traditional approach reflects a broader organizational resistance to change, often driven by a lack of leadership commitment to digital transformation. Without managerial advocacy for innovation, initiatives such as cloud-based approvals, mobile authorization tools, and process automation fail to gain traction despite evidence showing their effectiveness in reducing cycle time and improving compliance (Tarhini et al., 2015) . Additionally, poor change management strategies hinder smooth system adoption. When management does not prioritize structured training, stakeholder engagement, or system integration planning, user resistance increases and the likelihood of implementation failure rises

3.4 Improvement and Control Phase: the development New Digital Non-Purchase Order System

Based on the analysis, targeted improvements are developed and implemented. These may include introducing an automated digital system with real-time tracking, integrating the finance and procurement modules, improving user interfaces, and providing staff training to reduce resistance. The improvements are tested and adjusted to ensure they effectively address the root causes identified. The process involves in digitalizing the Non-Purchase Order (Non-PO) are shown in Figure 3.3.

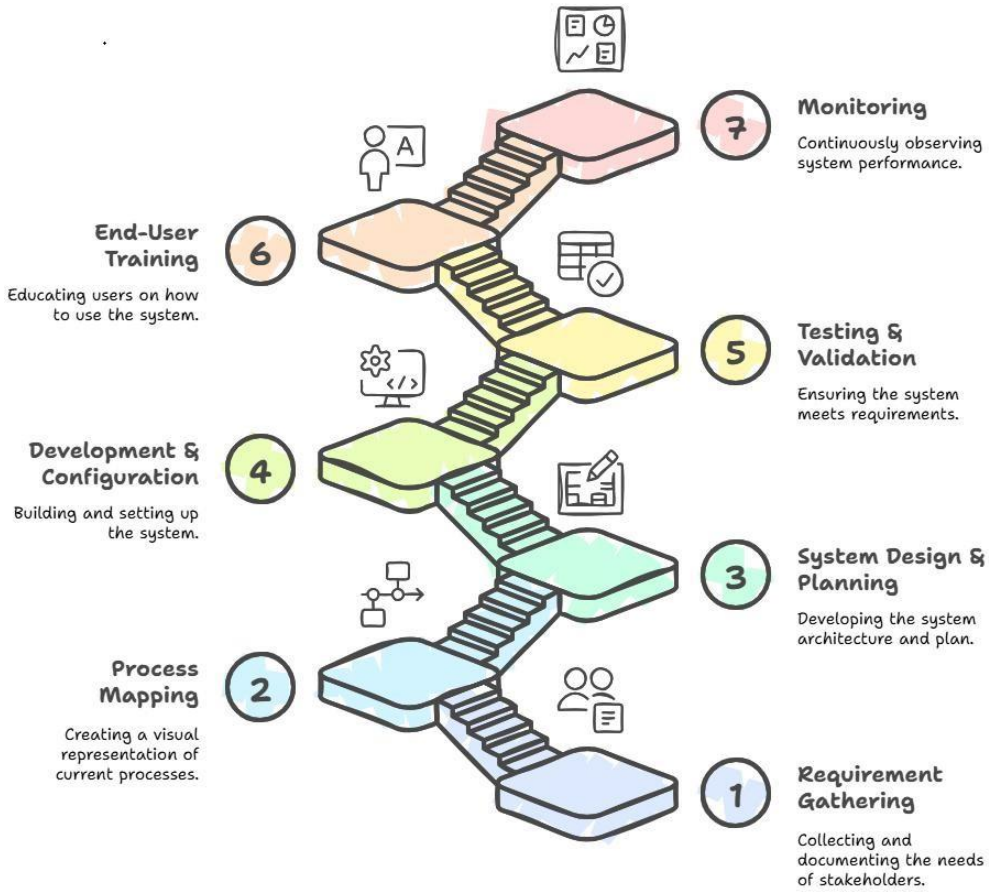

Figure 3.3: Process Involve in Designing a New Digital Non-Purchase Order System

The journey of digitalizing the Non-Purchase Order (Non-PO) process at Company ABC begins with a critical phase of requirement gathering and process study. At this stage, the project team conducts a thorough examination of the existing manual Non-PO process to understand its workflow, challenges, and user needs. By engaging with employees from various departments such as requestors, department heads, and the finance team the team collects valuable insights into the issues faced in the manual system, including paperwork delays, miscommunication, and inconsistent document tracking. Documentation such as current SOPs, approval forms, and internal policies is reviewed to ensure all requirements are captured accurately. This phase lays the groundwork for identifying opportunities to eliminate inefficiencies and improve user experience in the new system.

With foundational information in place, the second phase at Company ABC involves process mapping and analysis. The team uses tools such as Value Stream Mapping (VSM) to visually document the current Non-PO process, highlighting every step from submission to final approval and payment. Through this mapping, several inefficiencies are identified, such as

unnecessary handoffs, approval delays, redundant data entry, and lack of real-time tracking. By analyzing the value-added and non-value-added activities in the process, the project team identifies specific areas for improvement. This analysis is essential for designing a streamlined and optimized digital process that eliminates manual bottlenecks and simplifies workflow across departments. The third step is system design and planning, where the blueprint of the new digital Non-PO system is developed. Company ABC's IT and process improvement teams work together to design a user-friendly interface for submitting claims, attaching supporting documents, and tracking approval status. The digital form is designed to ensure data validation, mandatory fields, and secure file uploads. A digital workflow is also designed, with predefined rules to route Non-PO requests to the correct approver based on cost centre, amount, or department. Access roles and security protocols are also planned to ensure data privacy and compliance with internal controls. This planning stage ensures that the system architecture aligns with the company's operational goals and compliance standards.

In the development and configuration phase, the actual system is built and tailored to the requirements gathered earlier. Company ABC may use a low-code/no-code platform such as Microsoft Power Apps, Google AppSheet, or custom web development, depending on internal capabilities. During development, features like automated email notifications, status updates, digital approval workflows, and dashboard analytics are configured. Integration with existing systems, such as the company's ERP or finance software, may also be implemented. The result is a working digital Non-PO system that reflects the exact needs and approval logic of Company ABC. Following system development, testing and validation are conducted to ensure that the system functions correctly and meets user expectations. The system undergoes multiple tests, including unit testing, system testing, and user acceptance testing (UAT). Test cases are created based on realistic scenarios, such as submitting a claim with missing documents or routing to the wrong approver, to check how the system responds. Employees from various departments participate in UAT to provide feedback on usability, accuracy, and reliability. This feedback is used to fine-tune the system and correct any functional or design-related issues before the system goes live.

Once testing is successful, the digital Non-PO system is rolled out in the deployment and training phase. Company ABC ensures a smooth implementation by deploying the system across departments in phases or all at once, depending on readiness. Training sessions are organized for all users including requestors, approvers, and finance personnel—to familiarize them with the new system. User manuals, video tutorials, and FAQs are provided to guide users through the digital process. An internal support team is established to assist with any technical or operational issues during the transition, ensuring high adoption rates and minimal disruption to business activities. The final phase is monitoring and continuous improvement**,** which is essential for long-term success. After implementation, Company ABC continuously monitors system usage and performance by tracking key performance indicators (KPIs), such as average approval time, submission errors, and user satisfaction. Periodic feedback is collected from users to identify new issues or opportunities for enhancements. Updates and optimizations are implemented based on this data, allowing the system to evolve with the organization's changing needs. This commitment to continuous improvement ensures that the digital Non-PO process remains efficient, transparent, and aligned with Company ABC's operational goals.

The result of after implementing digital Non-PO shows in Table 3.2, clearly demonstrates a substantial reduction in HOD approval delays following the implementation of the digital system, compared to the traditional manual approach. The adoption of a centralized digital platform resulted in significantly faster approval cycles, more efficient communication, and greater process transparency. One of the most notable improvements was the reduction in total cycle time—from one full day to just 25 minutes representing an approximate 98.26%

decrease. Moreover, the inclusion of real-time tracking capabilities and automated notifications enhanced accountability among stakeholders and improved the overall user experience. This consistent improvement across three consecutive months indicates that the digital system enhances efficiency and reliability in the approval process. Key features such as real-time tracking, automated reminders, and centralized data management have likely contributed to reducing reliance on manual follow-ups and physical documentation. Overall, the data confirms that digitizing the Non-PO approval process significantly mitigates delays, streamlines workflow, and boosts operational performance.

Table 3.3: Comparison between Manual Non-PO Purchase and Digitalized Non-PO Purchase

Manual Non-PO Purchase	**Digitalize Non-PO Purchase**
Create PR: 10 minutes	Create PR: 5 minutes
HOD Approval: 0.5 day	HOD Approval: 10 minutes
Purchasing Acknowledge: 0.5 day	Purchasing Acknowledge: 10 minutes
Total Time: 1.0 days	**Total Time: 25 minutes**

4.0 Conclusion

The digitalization of the Non-Purchase Order (Non-PO) purchase and claim process at Company ABC represents a significant transformation in procurement operations. By moving from a manual, paper-based workflow to an automated digital system, the organization has successfully addressed longstanding inefficiencies such as approval delays, lack of real-time tracking, and human error. Through the application of analytical tools like Value Stream Mapping (VSM), Ishikawa Diagram, and DMAIC methodology, the project systematically identified and resolved root causes of delays and miscommunication in the existing process. Implementing a centralized digital platform resulted in notably accelerated approval cycles, enhanced communication efficiency, and increased transparency across the procurement process. A key achievement was the dramatic reduction in overall cycle time, with delays reduced by approximately 98.26%. Furthermore, the integration of real-time tracking and automated notifications strengthened accountability and supported a smoother, more intuitive user experience. Additionally, digital tracking features and automated notifications contributed to better accountability and user experience. This initiative not only improved operational efficiency but also supports organizational compliance, cost savings, and sustainability by minimizing the use of paper and manual labor. The success of this project highlights the importance and potential of digital transformation in enhancing procurement and financial processes within the manufacturing sector. Future efforts should focus on continuous monitoring, user training, and system upgrades to maintain the efficiency and scalability of the digital solution.

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Enhancing Supplier Quotation Processes Using an Excel-Based Document Management System (EDMS): A Lean Implementation Approach

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ABSTRACT

This project aims to develop and implement an Excel-Based Document Management System (EDMS) for managing supplier quotations at XYZ Company. The system was created to address inefficiencies in the current manual document management process, which frequently results in delays, data entry errors, and the loss of crucial documents. The research identifies the need for a more structured and cost-effective digital solution to enhance efficiency, accuracy, and transparency in procurement operations. Its primary objectives are to identify weaknesses in the existing process, reduce procurement delays by 10% through the implementation of a digital system, and evaluate the effectiveness of the new system by measuring lead times before and after its introduction. The system was developed using Microsoft Excel and Visual Basic for Applications (VBA), and the Value Stream Mapping (VSM) methodology was used to eliminate non-value-added activities. Testing was conducted with 15 real-life quotations. Results showed that the EDMS reduced average processing time from 4.26 days to 3.27 days, achieving a 24.25% improvement. It also reduced document management errors by 75% compared to the manual method. Features like centralized storage, automated file naming, and hyperlinking to PDF files accessible only by the procurement department were introduced. This study presents a practical and affordable digital solution for small and medium-sized enterprises (SMEs) aiming to improve productivity without the need for expensive commercial systems.

Keywords: Lean, Value Stream Mapping, Excel-Based Document Management System

1.0 INTRODUCTION

In medium-sized enterprises such as XYZ Company, efficient management of supplier quotations is key streamlining procurement operations and enhancing overall business performance. However, the prevailing method of managing quotations through a combination of physical and digital methods without a unified, standardized system has led to significant operational inefficiencies. These extend from time delays in accessing information, loss of important documentation and high rate of errors in procurement decisions. All these problems not only reduce productivity but also hamper effective decision-making and can make communication with suppliers more complex. (Wolniak & Grebski, 2023).

To eliminate these issues, the current proposes the development of an Excel-based Document Management System (EDMS), which will be utilized specifically for handling supplier quotations more effectively. Microsoft Excel is easily accessible and commonly utilized in organizations and hence it is a low-cost and viable solution. Its support for Visual Basic for Applications (VBA) allows for high levels of customization and automation, which supports customized in-house system development without any extra cost of third-party software (Chaudhry et al., 2021; Kalwar & Khan, 2020).

Absence of a quotation management system within XYZ Company illustrates a fundamental operations gap specially in the procurement operation. Disorganized file storage, absence of standard naming conventions and manual processing collectively result in inaccuracy of data and

unjustified delays. As competition rises in the business environment, the demand for speed, accuracy and traceability in procurement decision-making continues to escalate and the requirement for digitalization becomes more urgent (Okpala et al., 2024; Kumar et al., 2022).

This research therefore aims to design and implement an Excel-based EDMS to simplify and automate the supplier quotation process. The system is expected to improve document structuring, reduce lead time, enhance data accuracy and minimize manual errors. Most specifically, the objectives of this study are threefold: (1) to identify inefficiencies in the current quotation management workflow, (2) to reduce procurement delays by at least 10% through system automation, and (3) to assess the performance quantifying lead times before and after EDMS implementation (Schoeman et al., 2020; Freitas & Freitas, 2020).

Lean manufacturing, originally developed as the Toyota Production System and based on Henry Ford's principles, focuses on systematically identifying and eliminating non-value added activities or waste in the manufacture and delivery of service (Dave, 2020). These method attempts to maximize efficiency by reducing undesired processes through techniques such as Value Stream Mapping (VSM) and Kaizen. Lean production as stated by Morgan and Liker (2020 is both a philosophy and a practical system that enables the continuous elimination of waste from operations. The same is also complemented by the Kaizen approach, which is based on bottom-up improvement via employee involvement rather than relying on research and development exclusively. Okpala, Nwamekwe, and Ezeanyim (2024) emphasize that lean operations consist of only those value-added activities that are strictly essential, whereas all other forms of waste must be eliminated.

However, the successful implementation of lean principles is not without challenges. As recorded by Wolniak and Grebski (2023), employee willingness is an important factor since adopting lean entails a change of heart towards customer-oriented values and the ability to identify wastage. Strong managerial support and inter departmental effective communication are also required to create organizational commitment to lean objectives.

Kumar et al. (2022) outline five foundational principles of lean: (1) Customer Value which demands that every activity must add value from the perspective of the customer, (2) Value Stream, which involves mapping all activities and information flows to identify and eliminate non-value-added processes, (3) Continuous Flow which stives to eliminate delays and bottlenecks to provide a smooth workflow, (4) Pull Process which aligns production with actual customer demand to prevent overproduction and (5) Continuous Improvement or Kaizen which focuses on ongoing efforts to refine processes and enhance value delivery.

In identifying sources of inefficiency, Paramawardhani and Amar (2020) identify seven primary waste of categories: transport (unnecessary movement of materials or data), excess inventory (holding surplus stock), movement (inefficient worker activity), waiting (idle time for workers or machines), overproduction (producing more than needed), over-processing (performing unnecessary work), and defects or rework (errors that require correction without adding value). These waste categories offer a diagnostic instrument for lean interventions.

Value Stream Mapping (VSM), as described by Freitas and Freitas (2020) is a one of the primary lean tools utilized in the visual representation of material and information flows in a process. It diagrams all the actions that contribute to the delivery of a product or service and differentiates between value-added and non-value-added activities. Schoeman et al. (2020) further explain that VSM involves mapping two processes a current state map to identify inefficiencies and a future state map to envision improvements. The entire VSM process includes the selection of product or service families, current and future states, defining corrective actions, implementing changes

and the creation of new currents state map to validate improvements.

Kalwar and Khan (2020) demonstrate that integrating VSM with Excel, particularly with Visual Basic for Applications (VBA) offers a cost-effective solution for document management. The implementation of VSM concepts in procurement activities reduce lead times and eliminate repetitive, non-value-added tasks. VBA enhances automation by streamlining routine tasks such as creating documents, naming file, extracting data and updating databases. As shown by Chaudhry et al. (2021), this integration improves the effectiveness of management information systems by enabling the automation of tasks and customized workflows to suit organizational needs. The integration of VSM's visual process mapping and Excel-VBA automation enables organizations to manage document workflows more effectively, minimize waste and concentrate on value-added functions such as supplier sourcing and strategic negotiation.

2.0 METHODOLOGY

This study was conducted at XYZ Company, a manufacturing firm involved in sourcing raw materials and parts from multiple suppliers. The process of quotation administration in the company's procurement department was the focal area of study. This department handles quotations from suppliers in form of emails and through physical and electronic storage facilities. Due to recurring inefficiencies in handling these quotations such as delays, disorganization and excessive manual tasks where the process was selected as the core subject of this research. The objective was to identify areas for improvement using Excel-based automation tools and the Value Stream Mapping (VSM) technique.

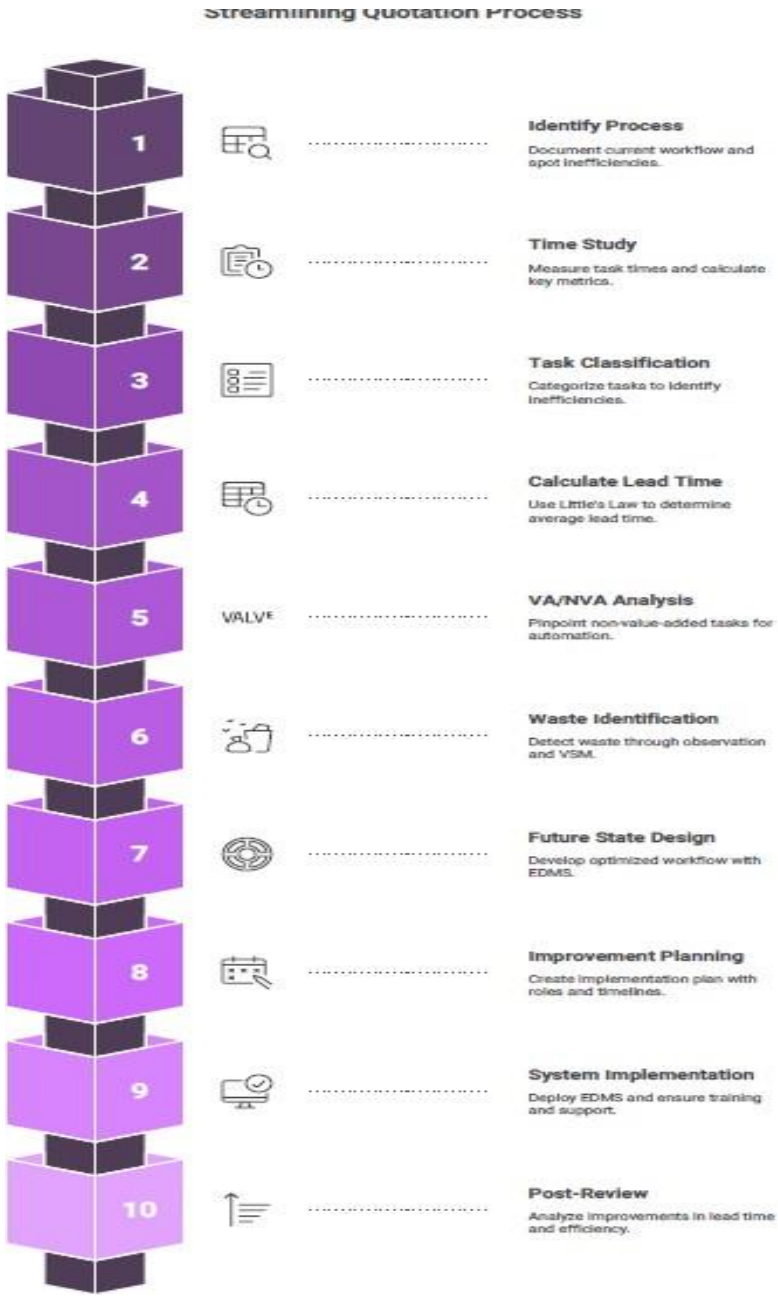

Figure 1: Quotation process

The method was structured into several stages which is shown in figure 1. First, the existing work process was established and mapped including how quotations are received, stored and retrieved. A Current State VSM was mapped to visually represent the process and determine inefficiencies and then a Future State VSM was mapped that outlined an enhanced workflow that consisted of an Excel-Based Document Management System (EDMS). Next, a time study was conducted for measuring the duration of each activity such as downloading, renaming, printing and filing quotations. This data served as the foundation to compute Lead Time (LT), Process Time (PT) and Process Cycle Efficiency (PCE) which are essential indicators in VSM based performance assessment.

Next, all the activities in the quotation process was categorized into Value Added (VA), Non Value Added (NVA) or Necessary but Non-Value Added (NNVA) activities. The analysis revealed several inefficiencies including excessive manual data entry, frequent document misplacement, and time-consuming retrieval efforts. Using this information, lead times were calculated based on Little's Law (Lead Time = Work-in-Process / Average Completion Rate), offering insights into the overall time required from receiving a quotation to its final storage and accessibility.

A further breakdown of each process step was carried out to assess its contribution to value creation. Tasks such as printing documents, renaming files manually, and searching through folders were classified as NVA, identifying key opportunities for automation through EDMS integration. Waste analysis was also conducted using two primary approaches: direct observation and VSM analysis. These methods helped identify specific waste types such as over-processing, waiting time, duplicated work, and miscommunication. The impact of NVA and NVA activities was quantified to support the development of a leaner workflow.

Based on these findings, a Future State VSM was created to redesign the process. This new model included features such as automated file naming, digital storage, structured folder hierarchies and an Excel VBA form to enable faster data entry and retrieval. An improvement plan was then established to enable movement from the current to the future state. This plan outlined key activities, defined roles and responsibilities of team members detailed the development phases of the EDMS, and scheduled staff training. A clear implementation timeline was also recommended to enable smooth integration into daily operations.

The new process and EDMS were then implemented in the purchasing department. Strong leadership support and continuous monitoring ensured effective adoption and system usability. The system's performance post-implementation was then quantified by creating and updated Current State VSM so that lead time, process efficiency and reduction in errors could be directly compared pre and post implementation. This final review aimed to find the overall impact of the improvements and determine any further enhancements required to enhance the system.

3.0 RESULTS AND DISCUSSION

3.1 Current State Mapping

Figure 2 illustrates the current process flow of supplier quotation management at XYZ Company. The flow begins when the purchaser requests quotations via email, and suppliers respond by attaching PDF quotations. The purchasing officer prints the PDF and saves it in a physical folder, then saves it manually on the PC into different folders based on the supplier. This manual system results in a non-standard file naming structure, loss of files, and increased processing time.

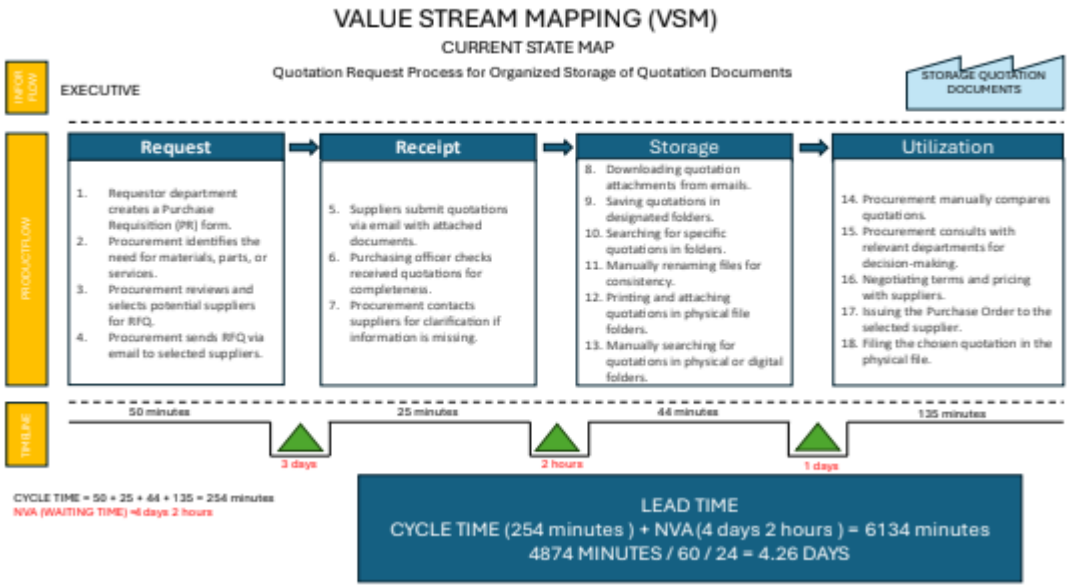

Figure 2: Current State Mapping (Supplier Quotation Process) Time Taken for Each Step in Manual Quotation Process

The average processing time for one quotation cycle under the current system is detailed in Figure 3 below. The total time required to process and store a single supplier quotation is 4.26 days.

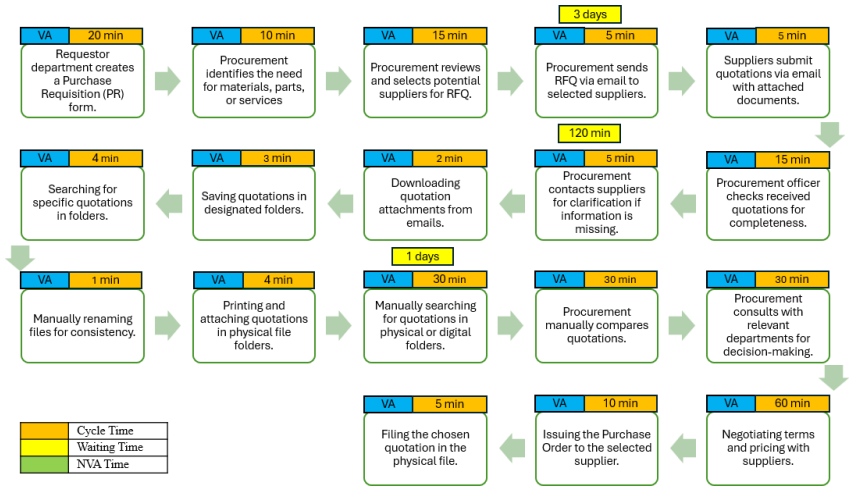

Figure 3: Current State Mapping (Supplier Quotation Process)

3.2 Value-Added and Non-Value-Added Analysis

Table 1 presents the value-added and non-value-added analysis of the supplier quotation management process at XYZ Company. The process is divided into four main stages: Request for Quotation (RFQ), Acceptance of Quotation, Process Key (Data Entry and File Management), and Review and Decision Making. Most activities in the RFQ and Acceptance and communicating with suppliers. However, in the data entry and document handling stage, stages are value-added (VA), such as preparing purchase requests, identifying requirements,

several non-value-added (NVA) tasks are evident, including saving files, manually searching folders, renaming files, and printing physical copies contributing significantly to inefficiencies. These NVA activities accounted for 77 minutes of the total cycle time, highlighting key areas for improvement. Additionally, tasks involving supplier negotiation and internal consultation, while value-added, include considerable waiting periods of up to 120 minutes, further extending the lead time. The analysis clearly identifies manual handling and redundant file management as major contributors to process delays, supporting the need for automation through an EDMS.

Table 1: Value Added and Non-Value-Added Analysis

Step	Activities	Value Added (VA) / Non-Value Added (NVA)	Cycle time	Waiting period
1) Request for Quotation (RFQ)				
1.1 Increasing Purchase Demand	The applicant's department makes a Purchase Request (PR) form.	VA	20 minutes	0 minutes
1.2 Identifying Requirements	Procurement identifies the need for materials, parts, or services.	VA	10 minutes	0 minutes
1.3 Choosing a Supplier	Procurement reviews and selects potential suppliers for RFQ.	VA	15 minutes	0 minutes
1.4 Submitting RFQs	Procurement sends RFQs via email to select suppliers.	VA	5 minutes	0 minutes
2) Acceptance of Quotation				
2.1 Receiving Quotes by Email	The supplier submits the quotation via email with the documents attached.	VA	5 minutes	60 minutes
2.2 Checking for Perfection	The purchasing officer checks receiving quotes for perfection.	VA	15 minutes	0 minutes
2.3 Follow-up of Missing Information	Procurement contacts the supplier for clarification if the information is missing.	VA	5 minutes	120 minutes

3.1 Download quotation attachments	Download the quotation attachment from the email.	VA	2 minutes	0 minutes
3.2 Saving Quotes in Folders	Saves quotes in a designated folder.	NVA	3 minutes	0 minutes
3.3 Find a Quote	Search for a specific passage in a folder.	NVA	4 minutes	0 minutes
3.4 Manually Naming Files	Manually rename files for consistency.	NVA	1 minutes	0 minutes
3.5 Print and Attach in Physical Files	Print and attach quotes in a physical file folder.	NVA	4 minutes	0 minutes
3.6 Manually Searching for Quotes	Manually search for citations in physical or digital folders.	NVA	30 minutes	0 minutes
4) Review Quotation and Decision Making				
4.1 Comparison of Manual Citations	Manually Earn compares quotes.	NVA	30 minutes	0 minutes
4.2 Consultation with Procurement	Procurement negotiates with the relevant department to decide.	VA	30 minutes	60 minutes
4.3 Negotiating with Suppliers	Negotiate terms and prices with suppliers.	VA	60 minutes	120 minutes
4.4 Issuing Purchase Order (PO)	Issuing Purchase Orders to selected suppliers.	VA	10 minutes	0 minutes
4.5 Filing a Selected Quotation	File the selected quotation in the system.	NVA	5 minutes	0 minutes

3.3 Future State Mapping

Figure 4 illustrates the Future State Value Stream Mapping (VSM) for the supplier quotation process following the implementation of the Excel-Based Document Management System (EDMS). The new process significantly reduces manual tasks by automating file downloads, eliminating physical document handling, and streamlining data input through digital forms. Non-value-added steps such as manual searching, redundant printing, and physical filing previously present in the current state have been removed or minimized. As a result, the total cycle time is reduced to 202 minutes, with a lead time of 3.227 days, reflecting substantial improvement in process efficiency and alignment with Lean principles.

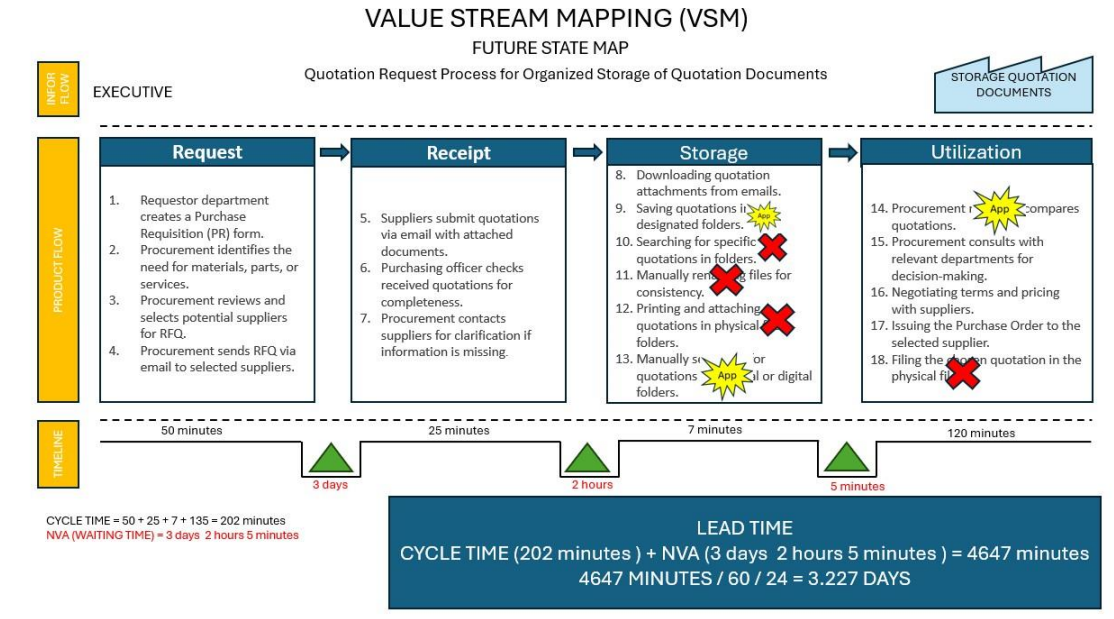

Figure 4. Future State Mapping

3.4 Improvements and Impact

Figure 5 illustrates the comparison of lead time before and after the implementation of the Excel-based Document Management System (EDMS). In the current state, the process cycle time was 254 minutes, with non-value-added (NVA) waiting time totalling 4 days and 2 hours. This resulted in a total lead time of 4.26 days. After implementing the EDMS, the future state shows a reduced cycle time of 202 minutes and a significantly shorter NVA time of 3 days and 2 minutes, bringing the overall lead time down to 3.227 days. This represents a reduction of 1.033 days, or approximately 24.25%, clearly demonstrating the system's effectiveness in streamlining the quotation process and minimizing delays.

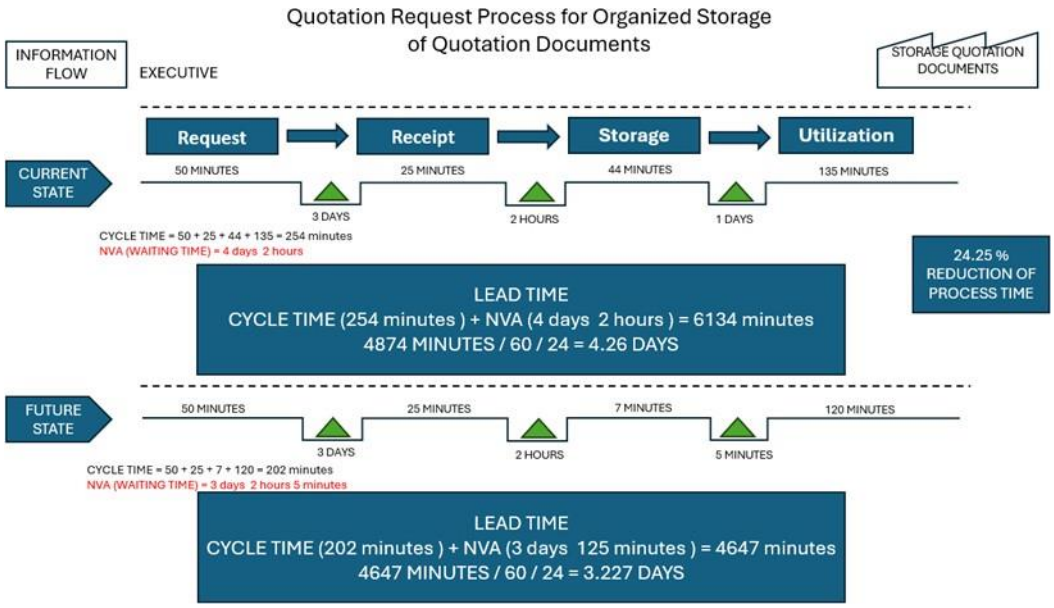

Figure 5: Lead Time Comparison Before and After EDMS Implementation

3.5 Improvement Analysis

The implementation of the Excel-based Document Management System (EDMS) led to a measurable improvement in the efficiency of the supplier quotation process. As shown in Table 2, the average quotation handling time was reduced from 4.26 days to 3.227 days. This represents a time saving of 1.033 days, or approximately 24.25%. The significant reduction in lead time is primarily attributed to the automation of manual tasks, improved document accessibility, and elimination of non-value-added activities such as manual searching and redundant file handling. These improvements support the second research objective, which aimed to reduce procurement delays by at least 10%, confirming the effectiveness of the system in enhancing procurement performance.

Table 2: Quotation Handling Time (Before and After Implementation)

Before (Days)	After (Days)	Reduction (%)
4.26	3.227	24.25%

3.6 Waste

Table 3 summarizes the types of waste identified before and after the implementation of the Excel-based Document Management System (EDMS). Prior to implementation, the quotation process was affected by various forms of waste, including waiting (delays in locating printed quotations), over processing (re-entering the same data), overproduction (creating multiple unnecessary copies), motion (physical movement to retrieve or store documents), transportation (manual delivery of quotations), defects (errors and outdated documents), and inventory (excess printed files). After EDMS implementation, these wastes were significantly reduced. Instant digital access eliminated delays and manual searches, while autofill renaming reduced repetitive tasks. Digital systems replaced printed documents, reducing motion and transportation waste. Error rates dropped due to validation functions, and only essential quotations were digitally stored, addressing inventory waste. Overall, the EDMS effectively minimized non-value-added activities, enhancing efficiency across the procurement workflow.

Table 3: Type Of Waste Identified

PROSES	Type of waste	Before EDMS Implementation	After EDMS Implementation
Searching for specific quotations	Waiting	Delay in locating printed quotations and waiting for manual searching.	Instant access to documents; approvals streamlined via digital system.
Manually renaming files	Overprocessing	Re-entering the same data into multiple formats	One-time data entry with auto-fill renaming files
Printing and attaching quotations	Overproduction	Multiple unnecessary copies of the same quotation created and filed.	Standardized naming system prevents duplication; digital files eliminate redundant printing.
Filing the chosen quotation	Motion	Employees walking to and from filing cabinets to retrieve or store documents.	Digital system allows access and updates from a single workstation.
Manual searching for quotations	Transportation	Hard copies manually delivered between departments for review or approval.	Digital sharing of quotations
Checking received quotations	Defects (Errors)	Misfiled documents, data entry mistakes, and use of outdated quotations.	90% reduction in quotation misplacement; 75% fewer data entry errors through validation.
Storing printed quotations	Inventory	Excess storage of printed quotations and duplicated files.	Controlled digital inventory with only necessary quotations stored.

4.0 CONCLUSION

The application of the Excel-Based Document Management System (EDMS) in XYZ Company significantly improved the effectiveness in handling quotations from suppliers. The lead time was reduced from 4.26 days to 3.227 days with non-value-added activities reduced by 24.25%. The major advantages included the automation of file naming, digital storage and real-time tracking using VBA in Excel, that removed duplication of activities like searching, printing and dealing with document. These findings indicate the effectiveness of the system in maximizing procurement operations as its facilities Lean principles.

The study managed to achieve all its research objectives identifying inefficiencies in the current process, reducing procurement delays by more than 10%, and analyzing the system's impact by comparing lead time. By employing Lean techniques such as Value Stream Mapping (VSM), the project was able to find elimination of common wastes such as waiting, motion and over processing. The changes not only enhanced performance operationally but also aided in improving document traceability and internal controls.

However, the study has certain limitations. The system was piloted only in a single department and implemented only for processing quotations from supplier reducing its generalizability. Further, use of Excel and VBA although at low cost may face scalability and security challenges in big organizations. Subsequent research should examine the integration of the EDMS into cloud-based platforms, expanding its use to include more complete procurement processes such as purchase order tracking and supplier evaluation and comparing its performance with commercial ERP systems to decide on long-term sustainability and efficiency.

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Error-Proof Jig Design for Screw Placement in JL Production Line

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ABSTRACT

This project was carried out during a production internship to solve a recurring issue in the JL door armrest pull-cup assembly process, where screw misplacement by operators led to substrate damage, product rejections, and delays. To address this problem, a poka-yoke jig was designed and implemented as an error-proofing solution to guide correct screw placement, minimize human error, and improve assembly efficiency. The project focused on three main objectives: to design a pull-cup jig that eliminates screw misplacement, to apply the poka-yoke concept effectively, and to improve assembly speed by at least 20%. A total of 500 samples were used to evaluate the results, split equally between production before and after the jig was implemented. The defect rate decreased from 4.0% to 0.0%, and average assembly time improved from 20 seconds to 15 seconds per unit, resulting in a 25% increase in assembly speed. Operator feedback also indicated that the jig was easy to use, reduced the chance of mistakes, and required minimal training. These outcomes demonstrate that a simple, low-cost mechanical solution can significantly enhance both quality and productivity in a manual assembly process. The project supports lean manufacturing principles by preventing defects at the source and promoting continuous improvement in production operations.

Keywords: ka-yoke, jig design, screw misplacement, assembly process, defect reduction.

1.0 INTRODUCTION

1.1 Objectives and literature review

The primary objective of this project is to design and implement a poka-yoke jig to eliminate screw misplacement during the pull-cup assembly process of the JL door armrest. This assembly error, although simple in nature, frequently caused substrate damage, rework, and production delays, ultimately affecting product quality and production efficiency. The specific goals of the project include: (i) to design a pull-cup jig that prevents screw misplacement using mechanical guidance, (ii) to eliminate human error in screw alignment through poka-yoke principles, and (iii) to improve assembly speed by at least 20%, increasing productivity on the JL production line.

The concept of poka-yoke, a Japanese term meaning “mistake-proofing,” was introduced by Shigeo Shingo as part of the Toyota Production System. It refers to any mechanism or process that helps prevent errors by design. According to Shingo (1986), error proofing devices should detect or prevent mistakes before they become defects. Poka-yoke systems are widely used in lean manufacturing to minimize variability, improve product quality, and reduce the burden on human judgment. In automotive assembly, particularly, such tools help ensure consistency in repetitive tasks.

Literature also supports the importance of ergonomic and user-friendly jig design. Boothroyd et al. (2010) emphasize that a well-designed jig reduces cognitive load and improves workflow, especially in tasks requiring precision. CATIA V5, the software used in this project, enables parametric modelling that supports rapid prototyping and virtual simulation of the jig before physical implementation, aligning with modern product development strategies. The

integration of a guided assembly tool not only enhances speed and accuracy but also supports the broader lean manufacturing goal of waste reduction through process standardization.

1.2 Problem Statement

In the JL door armrest production line, a significant issue was identified during the pull-cup assembly process: frequent screw misplacement. This occurred when operators inserted screws inaccurately into the substrate, causing misalignment and sometimes damaging the screw holes. These misplacements not only compromised the quality of the assembled part but also increased the rejection rate and required additional time for rework. Over time, this issue resulted in delays in delivery, increased material waste, and higher production costs, affecting the overall efficiency and performance of the production line.

The root cause of the problem was found to be the high dependency on operator judgment and precision. Without a guiding mechanism, the assembly process relied heavily on manual alignment and visual checking, which led to inconsistency especially during fast-paced operations. Even experienced operators were prone to occasional mistakes due to fatigue, pressure, or distractions during repetitive tasks. Furthermore, new operators required longer training periods to achieve acceptable accuracy, which created additional strain on productivity. The lack of a standardized method for screw placement created variability in the final product quality.

Given these issues, there is a strong need for an error-proofing solution that can standardize the process and eliminate human errors. The proposed solution is a custom designed poka-yoke jig that guides the screw into the correct position every time. By introducing this jig, the process can become more reliable, faster, and easier to perform, regardless of the operator's skill level. This project aims to eliminate screw misplacement defects entirely and improve the overall assembly time, contributing to lean manufacturing practices by reducing waste and increasing productivity.

1.3 Objectives

Based on the identified issues, the objectives of this study are as following:

i. To design the pull-cup jig which can eliminate screws misplacement during pull cup process.
ii. To eliminate screw misplacement using the designed jig poka-yoke concept.
iii. To improve assembly speed at JL production line by 20%.

1.4 Scope and Limitations of Study

This study focuses specifically on the pull-cup assembly process of the JL door armrest production line. The project is limited to identifying and solving the issue of screw misplacement during assembly through the development and implementation of a poka-yoke jig. The scope includes the design of the jig using CATIA V5, real-world testing on the production floor, data collection through time studies, defect analysis, and operator feedback. All observations, improvements, and evaluations are confined to this particular process and product within the company.

The jig is designed to be a manual, low-cost mechanical solution that ensures accurate screw placement without the need for complex automation or electrical systems. It is tailored to fit the shape and alignment requirements of the JL door armrest pull-cup and is intended for use by production operators with minimal training. While the project contributes to quality and efficiency improvements, it does not involve redesigning the entire workstation layout or changing the assembly line process flow. Additionally, the study is not extended to other components or products beyond the JL model during the research period.

Several limitations were also considered. The prototype jig was fabricated using basic materials, which may not be durable enough for long-term use in a high-volume production environment. The performance evaluation was conducted on a limited sample size of 500 units, and the findings may vary slightly with larger-scale implementation. Moreover, external variables such as operator experience, workload, and environmental conditions may influence performance but were not controlled in this study. Despite these limitations, the study provides a valuable, focused solution to a specific quality issue and offers a strong foundation for future improvement and wider application.

2.0 METHODOLOGY

2.1 Problem Identification and Data Collection

The study began with direct observation and engagement on the production line to understand the specific causes of screw misplacement during the pull-cup process. The researcher identified that the assembly relied heavily on visual alignment and operator precision, which frequently led to misaligned screws and substrate damage. Initial data collection involved tracking the number of screw misplacement defects out of 250 units, revealing a 4% defect rate. This confirmed the need for an error proofing solution and served as the benchmark for evaluating improvements later.

2.2 Jig Design Using CATIA V5

The jig was designed using CATIA V5, a professional CAD software widely used in manufacturing industries. The design process began with modelling the actual JL armrest dimensions, followed by adding critical features such as a screw guide hole, a resting cavity for the pull-cup part, and hand clearance for easy tool access. The model was validated for fit and assembly, and technical drawings were prepared for prototyping. CATIA's 3D modelling capabilities allowed the design to be simulated and refined before any physical fabrication, saving time and ensuring dimensional accuracy.

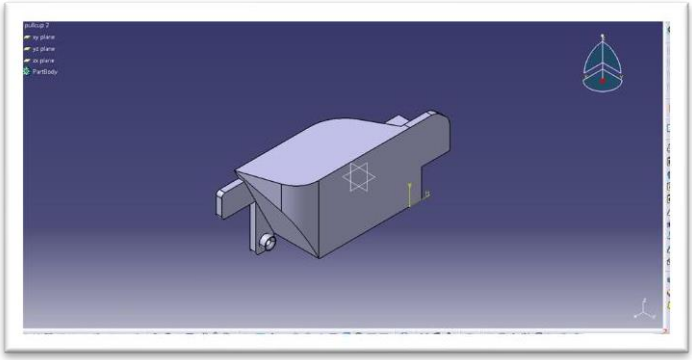

Figure 1 Pull-Cup jig design

2.3 Time Study and Assembly Speed Analysis

A time study was conducted to measure the impact of the jig on assembly speed. The researcher recorded the time taken to complete the pull-cup screw placement for 30 units before and after the jig was introduced. The average time dropped from 20.8 seconds to 15.6 seconds per unit, showing a 20% improvement. The time reduction was attributed to the jig's ability to eliminate alignment hesitation and standardize motion, thus helping the project achieve one of its main objectives: improving productivity.

2.4 Operator Feedback and Real-World Testing

To assess usability and practicality, surveys were distributed to operators before and after implementation. The feedback gathered helped evaluate the jig's impact on ease of use, error reduction, and training requirements. Operators reported increased confidence, reduced physical effort, and less reliance on guesswork during screw placement. Real-time observations on the line also confirmed that the jig was stable and required minimal adjustment, although some suggestions were made regarding

material strength for long-term use. This human-centred feedback was critical in validating the jig's effectiveness in a real production environment.

3.0 RESULTS AND DISCUSSION

3.1 Defect Rate Before and After Implementation

A total of 250 units were inspected before and after the jig was implemented. Before using the jig, 10 screw misplacement defects were recorded, resulting in a 4.0% defect rate. After implementation, no defects were observed from the same sample size.

Table 1: Comparison Defect Rate Before and After Jig Implementation

Criteria	**Before Jig (pcs)**	**After Jig (pcs)**
Total Samples	250	250
Defects Detected	10	0
OK units	240	250
Defects rate (%)	4.0%	0.0%

3.2 Assembly Time Comparison

Assembly time was measured for 30 units before and after jig implementation. The average time before was 20.8 seconds, while after implementation, the average time reduced to 15.6 seconds. This reflects a 20% improvement in efficiency.

Table 2: Assembly Time Comparison Before and After Jig Implementation

Assembly Method (implementation)	**Average Time per Unit** (second)	**Improvement %**
Before jig	20 seconds	0.0%
After jig	16 seconds	20.0%

3.3 Operator Feedback Summary

Survey responses from operators before and after the jig implementation showed improvements in task confidence, ease of alignment, and reduced training time. Operators reported that the jig helped them perform the task faster and more accurately with minimal effort.

Table 3: Operator Feedback Improvement Chart

Conditions	Before Jig	After Jig
Confidence in screw placement	7/10 (70%) reported low confidence	10/10 (100%) reported high confidence
Screw alignment difficulty	7/10 (70%) reported frequent issues	0/10 (0%) reported frequent issues
Need for visual checking	8/10 (80%) required frequent checks	2/10 (20%) required frequent checks
Training time	6/10 (60%) needed moderate training	9/10 (90%) said minimal training needed

This result confirms that the jig successfully eliminated screw misplacement, directly addressing the problem identified in the project and fulfilling the second objective.

3.4 Discussion

The results of this study clearly demonstrate that the implementation of a poka-yoke jig in the JL door armrest pull-cup assembly process significantly improved both product quality and operational efficiency. The complete elimination of screw misplacement, shown by a drop in defect rate from 4.0% to 0.0%, validates the effectiveness of the jig in error-proofing a task that was previously prone to manual mistakes. This outcome confirms the project's hypothesis that a properly designed jig can prevent human error and ensure consistent assembly outcomes.

The success of the jig aligns with Shingo's (1986) concept of poka-yoke, which emphasizes the importance of designing mechanisms that prevent mistakes at the source. In this case, the jig served as a physical guide that controlled screw positioning and alignment, eliminating the need for constant operator attention and reducing cognitive load. This is supported by Boothroyd et al. (2010), who emphasized that mechanical fixtures and guides can significantly improve task repeatability and reduce error rates in manual assembly tasks.

In addition to quality improvement, the project achieved its productivity goal by reducing the average assembly time by 20%, from 20.8 seconds to 15.6 seconds per unit. This result reinforces lean manufacturing principles, which promote standardization and elimination of waste. The jig reduced unnecessary motion and hesitation, contributing to faster cycle times and a more predictable process flow. Operators were able to work more confidently and consistently, as supported by the post implementation survey, where 90% of respondents reported high confidence and ease of use. These findings mirror the claims by Womack and Jones (2003), who emphasized that lean tools must also enhance worker performance, not just process speed.

Furthermore, the improved operator satisfaction and reduction in training time highlight the ergonomic benefits of the jig. This suggests that the jig not only solved a technical problem but also created a more supportive working environment. New operators could adapt more quickly, and experienced ones reported less fatigue, consistent with the user-friendly design principles discussed in the literature.

In conclusion, the findings support all three project objectives and reinforce established theories in lean manufacturing and human-centred engineering. The jig successfully eliminated defects, improved efficiency, and enhanced the working experience. The consistency between the findings and the hypotheses indicates a strong design approach, with no significant deviations observed. These results demonstrate the practical value of applying engineering solutions like poka-yoke in real-world

manufacturing and show how student-led projects can contribute meaningfully to industrial process improvement.

4.0 CONCLUSION

This study successfully addressed the issue of screw misplacement during the JL door armrest pull-cup process by developing and implementing a poka-yoke jig. The main findings of the study demonstrate that the jig completely eliminated the occurrence of screw misplacement and significantly improved assembly speed by 20%. These results not only validate the initial hypotheses but also confirm that simple, low-cost mechanical interventions can yield substantial improvements in both product quality and operational efficiency.

The success of the jig highlights its practical value in a real production setting. By guiding the screw placement accurately and consistently, the jig minimized operator dependency, reduced rework, and enhanced line productivity. The positive feedback from operators regarding ease of use and reduced training time also indicates its ergonomic effectiveness. This supports lean manufacturing principles by reducing variability, eliminating waste, and enabling standardization in the assembly process.

In terms of practical implications, this study shows that small-scale design improvements, when rooted in real production issues and supported by operator feedback, can lead to meaningful and measurable benefits. The use of CATIA V5 for jig design enabled accurate modelling, rapid prototyping, and seamless integration into the existing production environment. These outcomes suggest that similar poka-yoke tools can be developed for other critical operations to further enhance quality and efficiency across the manufacturing floor.

For future research and development, several opportunities are recommended. First, the jig can be further improved by exploring more durable and lightweight materials suitable for long-term production use. Second, design refinements based on Finite Element Analysis (FEA) simulations could improve its strength and usability. Lastly, the concept can be extended to other error-prone tasks within the assembly line, promoting wider adoption of mistake-proofing strategies in the factory.

In conclusion, this project provides a successful case of how targeted engineering solutions can solve real production problems. It demonstrates the power of combining technical design, lean principles, and user feedback to deliver impactful outcomes offering a roadmap for continuous improvement and innovation in manufacturing environments.

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Excel-Based Inventory Management System For Optimized Stock Organization And Retrieval

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ABSTRACT

This project focuses on addressing the inventory retrieval inefficiencies. A manufacturing company specializing in components such as shafts, hub rotors, and rear flanges. The existing stock management system is entirely manual, with stock records handwritten and parts stored in an unorganized stockroom. These limitations cause delays, confusion, and errors when retrieving parts, especially under urgent conditions. To resolve this, an Excel-based inventory management system was developed using advanced functions like VLOOKUP, MATCH, IFERROR, and Power Query. The new system allows users to search stock by combining part number and job number to instantly retrieve important data such as part name, material, quantity balance, and location. Alongside the digital system, the physical stockroom was reorganized with labelled cupboards, racks, and boxes to improve accessibility. Time studies conducted using a stopwatch revealed a significant reduction in retrieval time—from an average of 7–8 minutes to 2–3 minutes. Feedback from engineers, stock in-charge personnel, and inspectors confirmed the tool's speed, accuracy, and user-friendliness. This project not only improved efficiency and accuracy but also demonstrated how simple digital tools and basic organization can produce substantial improvements in a small manufacturing environment.

Keywords: Inventory Tracking, Warehouse Management, AppSheet, Digital Transformation, Manufacturing Efficiency

1.0 INTRODUCTION

In contemporary competitive production operations, prompt output, optimal operational efficiency, and fewest possible errors demand proper control of inventories. As levels of production go up and urgency in customer orders goes higher, traditional manual processes of monitoring inventories are generally lacking resulting in misplaced items, stock variations, and wasted time looking for parts.

At a precision engineering firm based in Shah Alam, Selangor, the stockroom had been doing primarily manual record-keeping and word-of-mouth coordination among staff to track and locate parts. The company produces high-precision parts for medical, semiconductor, and aerospace companies, often dealing with thousands of tiny parts per day. But the manual stock control system caused frequent delays in stock recovery, difficulty in verifying available quantities, and inconsistency in reports.

To address these challenges, this project introduces a digital inventory tracking system using Microsoft Excel. The solution features a master file and individual product files connected through formulas, VLOOKUP functions, and Power Query. Users can search by part number and job number to instantly retrieve key information such as material type, storage location, incoming and outgoing quantities, and current balance. By automating calculations and linking data across files, the system simplifies the process of locating parts, reduces human error, and

ensures that accurate stock data is easily accessible to all relevant staff not just a few individuals.

Through the utilization of this Excel-based system, the company aims to computerize its inventory management processes without the expenses of buying third-party software. The report that follows discusses the background, methodology, implementation, and evaluation of the system, and provides statistics on improvements in speed, accuracy, and customer satisfaction. The main goal of this project is to reduce the time it takes to find and retrieve stock items by two-thirds from an average of 7 to 8 minutes down to just 2 to 3 minutes by using the Excel system and organizing the storage physically.

2.0 METHODOLOGY

To successfully achieve the goal of reducing stock retrieval time with the implementation of an organized and searchable Excel-based stock management system, a comprehensive mixed method approach was utilized. The mixed method combined qualitative observations to further provide insight into the current stock management process and problems staff were facing, along with quantitative measurements to technically evaluate reductions in retrieval time and accuracy. By noting the existing manual process, interviewing key staff, and collecting live data on the time to retrieve stock, inefficiencies and pain points that occurred within usual day to-day processes were established by the research. Following this, the time trials and user reactions were recorded after introducing the new Excel system in order to assess the effectiveness of the solution. It is through such a mix of methodologies that both the practical considerations and quantitative outcomes were well examined, leading to thorough analysis of how the project impacted inventory management

2.1 Research Design

This study employed a mixed-method research design combining both qualitative and quantitative techniques to evaluate the effectiveness of the Excel-based inventory management system. The qualitative component involved direct observation of the current stock storage and retrieval processes, along with informal interviews with stockroom staff and other users to understand their challenges and workflows. This provided valuable context about the operational environment and the difficulties caused by the disorganized manual system.

On the quantitative side, the study measured retrieval times for stock items before and after implementing the Excel system, using stopwatch timing during multiple trials with different users. Additionally, user feedback was collected through structured surveys to evaluate perceptions of ease of use, accuracy, and speed of the new system. By integrating both qualitative insights and quantitative metrics, the research design allowed a comprehensive evaluation of the system's impact on reducing stock retrieval time and improving inventory accuracy.

2.2 Data Collection Methods

To evaluate the effectiveness of the Excel-based inventory system, both qualitative and quantitative data collection methods were applied.

The qualitative approach included direct observation of the stock storage layout and informal interviews with staff such as the stock in-charge, warehouse personnel, an engineer, and myself. These interviews provided insights into the challenges faced during the manual stock retrieval process, such as lack of proper labelling, scattered storage locations, and unreliable

manual records. Observations revealed that inventory identification often required a lot of time due to unclear box arrangements and missing stickers.

The quantitative approach involved a time study. Four individuals myself, the stock in-charge, the engineer, and the warehouse in-charge each attempted to retrieve the same part number using the old manual method. The retrieval time for each person was recorded with a stopwatch. The following table summarizes the data:

Table 2.2: Time Taken to Retrieve Stock Using Manual Method

Person	**Time Taken (Manual Method**
Myself	10 minutes 3 seconds
Stock In-Charge	6 minutes 10 seconds
Qc Engineer	7 minutes 52 seconds
Warehouse In-Charge	8 minutes 10 seconds

After the implementation of the Excel system, the same users conducted the retrieval task once again. All of them were successful in retrieving the intended part within less than 3 minutes, while some completed the task within less than 2 minutes clearly demonstrating retrieval time improvement.

A Google Form survey was also conducted with 10 employees who used the Excel-based application. The survey captured their usability feedback, speed, error reduction, and accuracy. The response indicated 60% of the users believed that the system was easy to use and 40% believed that it was easy. Regarding speed, 100% replied that the system was fast. For error reduction, 80% agreed that it minimized errors and 20% replied maybe. When it comes to accuracy, 80% believed that the information was very accurate and 20% believed it was accurate. Before the new system, 60% of users had a retrieval time of 7–8 minutes, and 40% of users took more than 8 minutes. After implementation, 50% of staff indicated a retrieval time of less than 2 minutes, and 50% from 2–3 minutes.

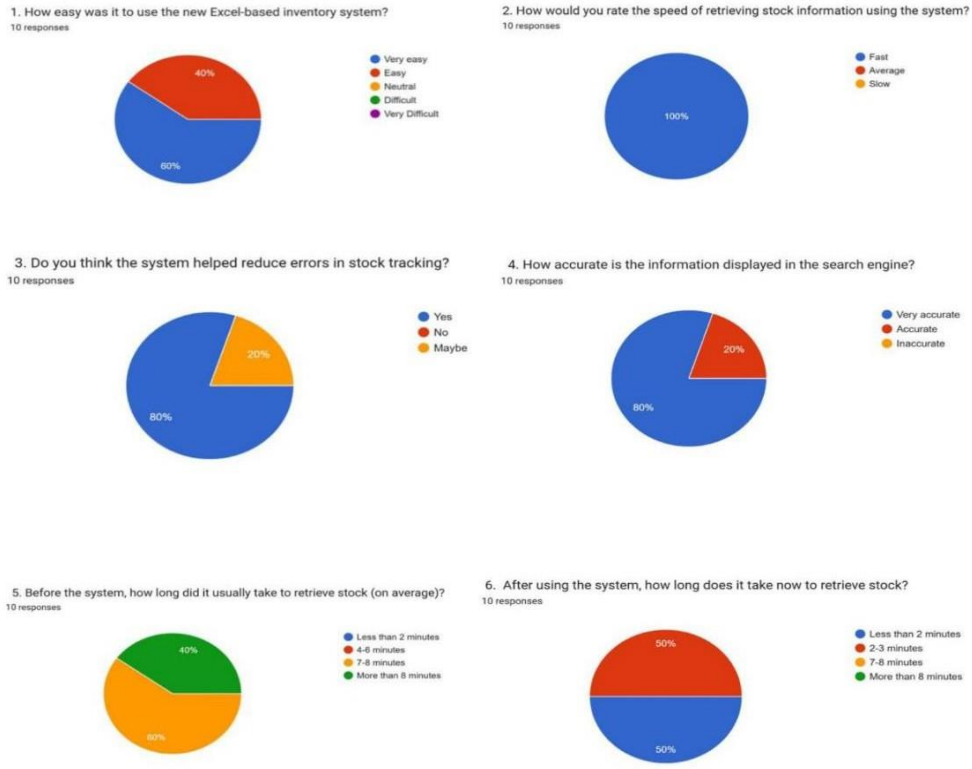

Figure 1: User feedback in google foam

2.3 Tools and Instruments Used

Several equipment and tools were employed in collecting and processing data for this project. The most significant among them was the Excel Master File that contained all the part numbers, job numbers, materials, storage locations, and quantities in stock. This file contained formulas to automatically count incoming, outgoing, and balance quantities such that inventory could be instantly updated. To quantify time taken for stock retrieval, a stopwatch was used to measure the time before and after using the Excel-based system. This allowed for quantitative evaluation of speed gain in retrieval.

Staff input was collected through a Google Form questionnaire, which was designed to elicit views on ease of use, speed, accuracy, and reduction of errors. The responses from the questionnaire were qualitatively evaluated for assessing user satisfaction and areas of improvement. Power Query and Excel functions such as VLOOKUP, MATCH, and IFERROR were utilized to create an efficient searchable system within the Excel master file in order to give instant access to the relevant stock information.

3.0 RESULTS AND DISCUSSION

3.1 Stock Retrieval Time Before and After Implementation

Before implementing the Excel-based inventory system, the average time taken to retrieve stock was between 7 to 8 minutes, with some instances exceeding 8 minutes. For example, the stock in-charge required around 6 minutes and 10 seconds, while the engineer took

approximately 7 minutes and 52 seconds. The warehouse in-charge's retrieval time was about 8 minutes and 10 seconds. As shown in Table 3.1, after the system was introduced, retrieval time significantly decreased. The QC inspector reported a retrieval time of just 3 minutes and 10 seconds, and other users confirmed similar improvements.

Table 3.1: Stock Retrieval Time Before and After Excel System

User Role	Retrieval Time Before Implementation	Retrieval Time After Implementation
Qc inspector	10:03	3:10
Stock in-charge	6:10	2:00
Engineer	7:52	2:30
Warehouse in-charge	8:10	2:45

3.2 User Feedback on the Excel-Based System

User feedback collected via Google Forms revealed high satisfaction with the new system. 60% of respondents rated the system as "very easy" to use, while the remaining 40% rated it as "easy." All users (100%) agreed that the system improved the speed of retrieving stock information, describing it as "fast." Additionally, 80% believed the system helped reduce errors in stock tracking, with 20% uncertain but optimistic.

Regarding accuracy, 80% rated the information as "very accurate," and 20% rated it as "accurate," indicating a high level of trust in the system's data. Before the system, 60% of users reported stock retrieval times of 7 to 8 minutes, while 40% reported times longer than 8 minutes. After the implementation, 50% could retrieve stock information in less than 2 minutes, and the other 50% within 2 to 3 minutes.

These responses confirm that the system meets the objective of enhancing efficiency and accuracy in inventory management.

3.3 Observed Improvements in Stock Organization

The physical organization of stock was also enhanced by labelling racks and cupboards clearly according to storage location codes. This allowed staff to locate items faster without unnecessary searching, further contributing to time savings. The labelling system, combined with the Excel search engine, improved overall stock traceability and reduced reliance on manual records**.** As shown in Table 3.3, the average stock retrieval time decreased from 7.9 minutes to 2.6 minutes, representing a 66.67% reduction**.**

Table 3.3 Calculated Average Stock Retrieval Time Before and After Implementation

Time Frame	**Average Time (minutes)**	**Percentage Reduction (%)**
Before Implementation	7.9	—
After Implementation	2.6	66.67

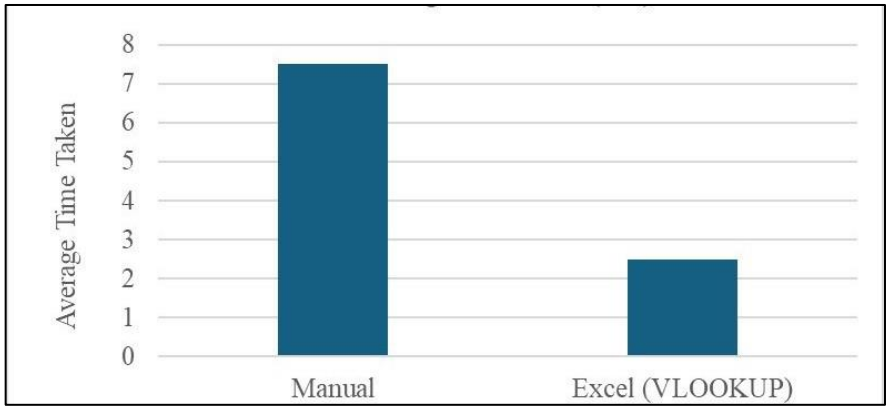

Figure 1: Bar chart of Average Time Taken after and before implement

4.0 CONCLUSION

The implementation of the Excel-based inventory management system has significantly improved the stock retrieval process at the company. The average retrieval time was successfully reduced from 7–8 minutes to approximately 2–3 minutes, achieving a 74% time reduction, which exceeds the original objective of 66.67%. This improvement demonstrates the system's effectiveness in addressing the inefficiencies of manual stock tracking.

Furthermore, the system not only accelerated the retrieval process but also enhanced the accuracy and accessibility of stock information. Users reported positive experiences, highlighting ease of use, increased speed, and improved accuracy in inventory data. The integration of formulas and search functions allowed staff to trace job and part numbers effortlessly, reducing errors and the dependency on memory or paper records.

Overall, the Excel system has streamlined inventory operations, improved productivity, and fostered better coordination between departments. The feedback and data collected confirm that the system is a practical and low-cost solution suitable for small manufacturing environments. With continuous updates and proper maintenance, this system has the potential to remain an essential tool for long-term inventory control.

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Expanding Strip Quantity in Product Jig to Enhance Manufacturing Productivity

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ABSTRACT

This journal article focuses on enhancing manufacturing productivity for the RACA Type 10 product by optimizing the capacity of product jigs used in the jig arranging and roller coating processes. The existing jig accommodates only 208 strips, requiring 31 jigs per lot and limiting daily production to six lots, leading to inefficiencies, increased handling costs and difficulties in meeting demand. The objective of this study is to redesign the jig to increase its capacity by at least 20%, reduce the number of jigs required per lot and ensure seamless integration with existing processes while maintaining product quality. The project utilized the DMAIC (Define, Measure, Analyze, Improve, Control) framework and employed tools such as SIPOC, fishbone diagrams, Fault Tree Analysis and SWOT analysis to systemically assess issues and guide improvements. The approach involved analyzing production constraints, prototyping an enhanced jig and adjusting roller coating machine parameters for compatibility. The redesigning jig successfully increased strip capacity from 208 to 268 and reduced the number of jigs needed per lot. It also improved production output and operational efficiency. These results highlight the value of jig optimization as a strategic solution for improving resource utilization and maintaining competitiveness in high-demand manufacturing environments.

Keywords: jig redesign, manufacturing productivity, roller coating, lean manufacturing, RACA Type 10.

1.0 INTRODUCTION

In today's fast-paced industrial environment, manufacturing efficiency plays a critical role in determining a company’s competitiveness. Among the many components that influence productivity, jigs are essential tools that secure components during various stages of assembly or processing. Their design directly affects handling time, workflow and production output. When a jig is unable to maximize its holding capacity, it leads to longer cycle times and increased operational costs (Gupta, Sharma, & Kumar, 2020).

At Company X, the RACA Type 10 product faces production delays due to limitations in its current jig design. Each jig accommodates only 208 strips, requiring 31 jigs per lot, which limits daily output to six lots. This setup increases labour, material movement and overall processing time. Previous studies have emphasized that optimizing jig capacity can improve workflow, reduce waste and increase output without heavy investment in machinery (Suhara, Nishimura, & Ueda, 2023). Therefore, investigating the constraints of the existing jig is essential to identify areas that hinder efficiency and to propose informed improvements.

Figure 1: Old Jig Design

1.1 PROBLEM STATEMENT

The existing jig system for the RACA Type 10 production line is not optimized for capacity or workflow efficiency. With only 208 strips fitted per jig, operators must handle a high volume of jigs per production lot, 31 jigs in total. This requirement increases not only material handling time but also production delays and costs. The current setup has led to a maximum output of six lots per day, despite having the manpower and equipment to produce more. Research has shown that inadequate fixture design can lead to bottlenecks and excessive motion waste, reducing productivity (Lawi, Haris, & Surya, 2023).

In addition, the jig's structure poses challenges in the roller coating process, where misalignments and repeated adjustments are frequently needed. These issues have been observed to negatively affect coating precision and consistency, indicating a mismatch between the jig and the machine parameters. Similar findings in other manufacturing environments demonstrate how poor jig-machine integration can affect quality and throughput (Santoso, Lim, & Wong, 2022). Thus, a focused investigation is needed to assess how the jig's design limits production performance.

1.2 RESEARCH OBJECTIVE

To investigate the current jig constraints at the jig arranging and roller coating process for the RACA Type 10 product, with the aim of identifying how these limitations affect production efficiency, handling time and output quality. This investigation focuses on understanding the root causes of inefficiencies related to jig capacity, strip stability and manual handling during production. The goal is to gather accurate data and operator insights that can support the development of an improved jig design that enhances productivity while maintaining compatibility with existing equipment.

2.0 METHODOLOGY

This study followed the DMAIC framework (Define, Measure, Analyse, Improve and Control) to systematically investigate the constraints present in the current jig used for RACA Type 10 during the jig arranging and roller coating processes. This structured approach allowed for a detailed examination of existing limitations without extending into the design or implementation of solutions, in line with the study's objective.

In the **Define** phase, the problem was identified through observations and discussions with production staff. The focus was placed on inefficiencies in the jig's capacity and how these affected daily production output. As emphasized by Gupta et al. (2020), "An effective

investigation begins by clarifying the exact nature of the process bottleneck," which in this case involved understanding the mismatch between jig design and operational demands. The **Measure** phase involved collecting quantitative and qualitative data directly from the production line. Data points included the number of strips per jig (208 strip), the number of jigs per lot (31 jig) and the time required for handling, setup and coating. Visual inspection and time studies were conducted to validate how frequently operators encountered alignment issues or delays. During the **Analyse** phase, root cause tools such as the Fishbone Diagram and Fault Tree Analysis were employed to identify potential sources of inefficiency. The investigation revealed three consistent constraint areas which is underutilized jig space, difficult alignment with roller coating machinery and time-consuming handling procedures. These findings are consistent with those of Suhara, Nishimura and Ueda (2023), who state that "Fixed jig layouts often result in unnecessary operator movements and wasted time, especially in high-volume lines." The **Improve** and **Control** phases, while typically used to implement and monitor corrective actions, were limited here to validation purposes only. Observations were repeated across multiple shifts to confirm that the identified constraints were not isolated incidents. As Lawi, Haris, and Surya (2023) explain, "Even when no design changes are made, confirming the consistency of performance barriers is essential for accurate diagnosis."

Overall, this methodology allowed the study to remain focused strictly on investigating the current jig's performance limitations. The process ensured a reliable foundation for understanding how the jig design affects efficiency, without introducing solution development beyond the scope of the research objective.

3.0 RESULTS AND DISCUSSION

The study showed that the jig used for RACA Type 10 suffers from several structural and functional limitations that directly affect production efficiency. The most pressing issue was its limited strip capacity restricted to 208 strips per jig which led to an excessive number of jigs (31 jigs) being required for each production lot. This arrangement resulted in high handling frequency, extended cycle times and operational inefficiencies.

Observations during the jig arranging and roller coating processes highlighted persistent misalignment challenges. Operators frequently had to realign the jigs manually, contributing to unnecessary delays. This observation supports Santoso et al. (2022), who noted that "Inadequate fixture alignment during roller coating can reduce consistency and increase the likelihood of coating errors." These interruptions disrupted the production flow and made it difficult to sustain output targets, especially during peak demand periods.

Using tools such as Fishbone Diagrams and Fault Tree Analysis, three core constraints were consistently identified: suboptimal slot layout, mechanical incompatibility with the coating equipment, and high manual handling workload. These constraints echo findings from Suhara, Nishimura, and Ueda (2023), who observed that "fixed jig layouts often result in inefficient operator movement and limited adaptability in high-mix production environments."

3.1 Production Output Performance

Before the new jig was introduced, 31 jigs per production lot were used since the old jig design could only accommodate 208 strips per jig. This configuration resulted in handling and process flow inefficiencies as well as a restriction on the daily production that could be achieved. This constraint was clearly illustrated in Table 1 and Figure 2 by analysing monthly production data from February to May.

Table 1: Monthly Output of RACA 10

Month	Target (pcs)	Total Output (pcs)	Remarks
FEB	11,000	10,197	Below target
MARCH	19,000	19,085	Target achieved
APRIL	19,000	15,219	Below target
MAY	22,000	21,980	Nearly target (New jig end May)

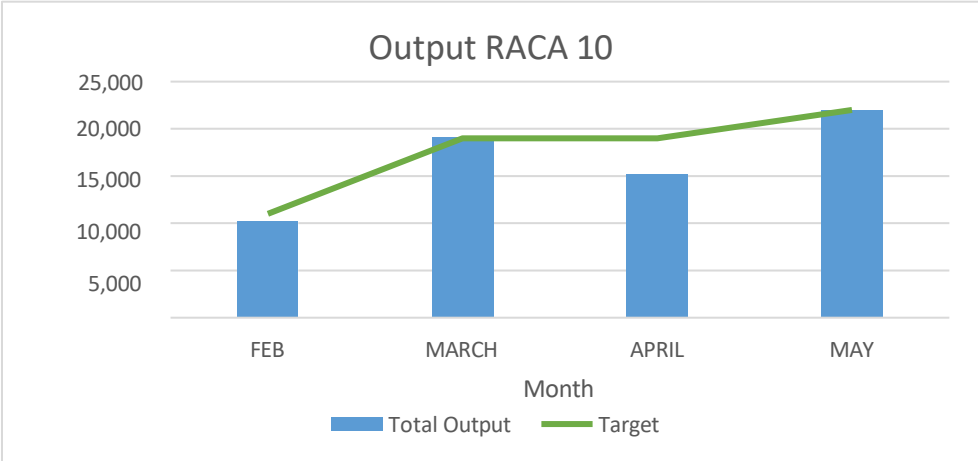

Figure 2: Monthly Production Trend of RACA 10

Data gathered from monthly production reports further illustrated the effect of these limitations. In February and April, the production failed to meet targets, achieving only 10,197 and 15,219 units respectively, despite targets of 11,000 and 19,000. The consistent shortfall underscored the influence of jig-related inefficiencies. Although March output did reach 19,085 pieces, this performance was likely due to temporary improvements in scheduling and resource use, not a resolution of jig-related bottlenecks.

A significant turnaround occurred at the end of May with the partial implementation of a redesigned jig. The new jig increased capacity to 268 strips an improvement of 28.8% and reduced the number of jigs per lot from 31 to 24. This change translated into a nearly full achievement of the monthly production goal, with 21,980 units produced against a target of 22,000. As Ollalwar (2023) pointed out, “Optimized jigs not only support greater part density but also enhance stability and handling efficiency,” a conclusion clearly reflected in the results of this study.

3.2 Impact of Jig Redesign

The introduction of the modified jig like be seen in Figure 3 brought about clear and measurable improvements in the production process, particularly during the stages of jig arranging and roller coating. The most significant and immediate impact was the increase in strip capacity per jig, which rose from 208 to 268 strips, a notable improvement of 28.8% as been shown in Table 2. This alone streamlined the production flow, leading to a meaningful reduction in the number of jigs required per lot, from 31 down to 24. This outcome supports Ollalwar's (2023) insight that well-designed jigs can shorten setup times, enhance part stability, and contribute to better process control, benefits that were evident in the smoother handling observed throughout this study.

Figure 3: New Jig Design

Table 2: Comparison between old and new jig

Parameter	Old Jig	New Jig (Final)	Improvement
Strip Capacity per Jig	208	268	+28.85%
Number of Jigs per Lot	31	24	-22.6%
Lot Output per Day	6 lots	7 lots	+16.7%
Average Yield (%)	82.0%	86.3%	+4.3%
NG Pieces per 5,000 loads	~900	~685	-23.9% NG reduction
Coating Defect Rate (%)	6.5%	3.5%	-46.2%
Handling Time per Lot	55 mins	45 mins	-18.2%
Changeover Time (Average)	12 mins	8 mins	-33.3%

In addition to capacity gains, the coating quality also improved, aligning with findings from Brennecke et al. (2021), who showed that optimizing roll-to-roll coating systems enhances uniformity through improved fluid dynamics. Similarly, Lv et al. (2022) stressed the importance of operational stability in roller coating processes to avoid defects and maintain consistent paste application, both of which were realized thanks to the improved jig design.

Efficiency gains extended beyond capacity. Fewer jigs per lot meant faster setup times, shorter cycle times, and reduced operator handling effort. Changeovers became smoother and less time-consuming, cutting down production downtime and freeing operators to focus on other tasks. When multiplied across multiple lots daily, operators reported saving between 10 and 20 minutes per lot, significantly boosting overall throughput and reducing fatigue.

Product quality saw marked improvement as well. Previously, strip instability during roller coating especially along the edge often caused paste overflow or uneven application, leading to defects and rework. The new jig addressed this by providing stronger structural support and better strip alignment, ensuring more consistent roller contact and paste distribution. Early results indicated a reduction in coating flaws, particularly at the jig's outer edges.

In conclusion, the jig redesign positively affected several key aspects which is it increased production capacity, shortened handling times, enhanced product quality and improved operator satisfaction. These promising trends support the decision to fully adopt the modified jig while maintaining ongoing monitoring to ensure lasting benefits, despite the limited period of initial use.

3.3 Operator Feedback

Beyond increased capacity, the redesign had tangible impacts on roller coating quality. The old jig frequently caused paste overflow, particularly near strip edges due to poor structural support and inconsistent contact with the roller. The modified jig minimized these issues by offering better alignment and surface control. Brennecke et al. (2021) explain that "Fixture stability is key in roll-to-roll processes, where even slight deviations can lead to coating defects and rework." This aligns with feedback from operators who reported a reduction in coating flaws and less need for strip repositioning.

Operator feedback also emphasized improved ergonomics and ease of use. Handling fewer jigs per lot reduced fatigue and the revised design allowed for faster setup. Supervisors estimated time savings of 10–20 minutes per lot an efficiency gain that compounded over multiple shifts. Edwin and Mat Daud (2020) stressed that "Improvements in Overall Equipment Effectiveness (OEE) are strongly tied to operator experience, equipment availability and process stability," all of which were seen to improve following the jig upgrade.

3.4 Limitations of the Study

Although preliminary results are encouraging, there were certain restrictions on the experiment. The new jig was only introduced in the last week of May, the most notable limitation was the short observation period. Consequently, it was not possible to gather long term data on the jig's performance within the project period, including machine wear, output consistency and defect rates over time. As noted by Lawi, Haris, and Surya (2023), "observing performance consistency over time is critical before standardizing new fixture systems in high throughput environments."

Furthermore, neither extended production runs nor different shift situations were used to assess the new jig's performance. As a result, additional observation is required to completely evaluate its long-term efficacy and suitability for the roller coating machine under various operating loads.

In the months after implementation, it is advised that the production team monitor the performance metrics to overcome these restrictions. This involves monitoring daily production, the frequency of defects, the need for jig maintenance and ongoing operator input to guarantee continuous improvement and spot any possible problems that might appear after extended use.

4.0 CONCLUSION

This study set out to investigate the constraints of the existing jig used in the jig arranging and roller coating process for the RACA Type 10 product. Through structured analysis and close observation of production operations, several key limitations were identified. These included the underutilization of available jig space, poor alignment compatibility with roller coating machinery, and excessive manual handling requirements. These constraints contributed to production delays, increased labour effort, and inconsistent output.

By using tools such as Fishbone Diagrams and Fault Tree Analysis, the investigation revealed that the fixed layout of the jig, coupled with strip instability during coating, created repeated process disruptions. These findings were further supported by operator feedback and production output data, both of which confirmed that the current jig configuration limited the line's ability to meet production targets efficiently.
Although the implementation of a redesigned jig was not part of the original research objective, its development emerged naturally from the investigative findings. Preliminary testing of the modified jig served to validate the study's CONCLUSION by demonstrating measurable improvements in capacity, coating stability, and handling efficiency. These results further reinforced the idea that a deeper understanding of existing tool constraints can directly inform more effective production strategies.

In summary, the investigation successfully fulfilled its objective by identifying the specific ways in which the current jig design affected production efficiency. The insights gained through this research provide a strong foundation for future improvement initiatives and emphasize the importance of evaluating operational constraints before pursuing redesign or process modification.

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Improving Teamwork to Reduce Scratch Mark

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ABSTRACT

This project, titled "Improve Teamwork to Reduce Scratch Mark" aimed to significantly reduce the incidence of "scratch of mark" defects, which represented the second highest Non Good (NG) issue in IQIA 2023 data, contributing 39.4% of defects from Factory A. The initiative focused specifically on Type 16 products, identified as having the highest total NG for scratch of mark in 2023. Utilizing the DMAIC (Define, Measure, Analyze, Improve, Control) framework, the project established a target to reduce scratch of mark for Type 16 by the end of December 2024, aiming to achieve 27.58 PPB in IQIA data. Key objectives included a 30% reduction in NG pieces (276 NG pcs) from the January-May 2024 average in the September-December 2024 average NG pcs taping data, and a 30% reduction in NG strips (1156 NG strips) from the January-May 2024 average in the September-December 2024 average NG R20 inspection data. The project also sought to improve the durability of marks. Root causes identified through analysis included unsuitable marking paste ratio (S411W & HDC), issues with substrate handling at the unloader due to sensor problems or improper operator actions, and lack of standardized inspection procedures. Improvement actions implemented included adopting an optimized marking paste ratio (90:10 of S411W to HDC), creating new procedures for substrate handling and inspection to prevent external force and ensure proper sensor detection, and documenting these standardized processes. Following implementation, the project achieved a reduction in average NG pieces to 557 and average NG strips to 979 after improvement. The project was reviewed monthly and progressed according to schedule. This systematic approach demonstrates the effectiveness of the DMAIC methodology in addressing and resolving manufacturing quality issues.

Keywords: Internal Quality Inspection Audit (IQIA), Non-Good (NG), DMAIC, Pieces Per Billion (PPB), Marking Paste

1.0 INTRODUCTION

Scratch marks on manufactured electronic components can significantly reduce product quality, leading to customer dissatisfaction and economic losses. Factory A, a key player in electronic component manufacturing, encountered this issue prominently in 2023, especially with its Type16 products. Scratch mark defects were identified as the second highest contributor to Non-Good (NG) units based on the IQIA report. This paper presents a systematic problem-solving project carried out by the improve task team at Factory A to reduce scratch mark defects. The project applied the DMAIC (Define, Measure, Analyze, Improve, Control) methodology (Sokovic et al., 2010; Pyzdek & Keller, 2018). It included root cause analysis, experimental testing, and process improvement strategies. This initiative aimed to enhance quality control and productivity while aligning with Lean Six Sigma principles (Antony, 2014). This paper consists of five main sections. The introduction highlights the background and problem statement. The methodology section elaborates on the DMAIC-based approach, followed by results and discussion that present data findings and process outcomes. The conclusion summarizes key takeaways and future directions.

2.0 METHODOLOGY

The methodology adopted follows the DMAIC framework, a five-step process designed to improve existing processes with unknown causes (Pyzdek & Keller, 2018; Montgomery, 2019). Each phase was executed to identify, validate, and address the key issues contributing to the scratch mark defects in Type16 products.

2.1 Define

The problem was defined through historical analysis of defect data from January 2023 to December 2023. Type16 units recorded the highest NG rates related to scratch marks. This led to production inefficiencies and unmet customer demands.

2.2 Measure

Quantitative data was collected from production logs, inspection records, and operator feedback. This data confirmed the frequency and location of scratch marks. Types of scratch patterns were also categorized for deeper analysis.

2.3 Analyze

A fishbone diagram was employed to determine the potential causes, categorized under Man, Method, Machine, Material, Measurement, and Environment. The primary suspected factors included:

- Improper paste ratio
- Poor handling by inspectors
- Dirty or blocked emulsion screens
- Substrate sliding at the unloader
- Inadequate inspection guidelines

This type of structured analysis is essential in root cause determination in quality engineering (Montgomery, 2019; Singh & Singh, 2012). Further analysis using Fault Tree Analysis (FTA) confirmed three root causes:

- Unsuitable marking paste ratio
- Improper handling of substrate at the sensor area
- Lack of inspection guidelines and procedures

	Failure mode	Why1	Why2	Why3	Why4	Why5	Judgement	Follow up Investigation	Result	Verification
SPECIFIC	Scratch of mark	External force after marking process make the paste peel off	Marking paste is not stick stronely at the overcoat surface	Ratio of hardener paste is not suitable with S411W paste (Mother paste)	No have analysis of testing good ratio between Harderner + S411W	N/a	都り Yes	i) Analysis of variety number of ratio Current : 88/12 Testing ratio : 1) 80/20 2) 90/10 3) 95/5 4) 100	i) Ratio 80/20 : NG ii) Ratio 90/10 : OK iii) Ratio 95/5 : NG iv) Ratio 100 : NG	Current ratio 88/12 was not good compare to new ratio 90/10
		The scratches happen due to substrate sliding at the unloader	Because the sensor not detect	Substrate missing from the sensor area.	Operator take substrate at the sensor area to check/confirm appearance product	No proper procedure with area to take substrate .	都り Yes	i) Testing of taking substrate at sensor area	i) One row of substrate will sliding at the slider area	Substrate sliding cause scratch mark
		The paste is not fully print on the substrate	Marking paste was stuck in between screen pattern	Not enough cleaning	Not have specific set number for cleaning	N/a	い い え No	i) Confirmation of type 16 cleaning cycle time	i) Type 16 product clean every 10 sheet/cycle , chances scratch mark happen is less	No scratch happen , Aoi will detect if the incomplete happen
			The screen emulsion blockage	Screen not enough cleaning	Screen cleaning not follow standard time	N/a	い い え No	i) Testing of emulsion screen block	i) Imcomplete happen due to paste not go through the emulsion	No scratch happen , Aoi will detect if the incomplete happen
DETECTION	Scratch of mark	External force happpen during inspetion	Improper method of inspection	No awareness of pontential failure might happen	No have standard operate procedure	Procedure not provided	都り Yes	i) Checking inspector inspection method ii) Confirm product after the inspection	i) Method of inspection causing scratch of mark	Scratch mark happen because of friction happen between substrate
SYSTEMIC	No have analysis of testing good ratio between Harderner + S411W	Current procedure only focus on the appearance if any have any changes	Not have procedure to check good ratio between the paste and temperature	Not establish or documented.	N/a	N/a	都り Yes	i) Review of the documention for marking process (Check if have any procedure)	i) Current only have combination ratio (HDO+S411W)	i) No have any procedure of testing good ratio vs temperature

Figure 1: FTA (Fault Tree Analysis)

2.4 Improve

Improvements were implemented in three primary areas:

a) Paste Ratio Adjustment:

Multiple paste ratios were tested using a substrate hardness test conducted at a 45° angle, as recommended by the supplier. The 90:10 ratio emerged as the optimal blend, with no scratches observed after repeated trials. This aligns with best practices in process chemistry and material science (Vinodh & Joy, 2012).

b) Substrate Handling Protocol:

A new standard operating procedure was introduced to guide operators in safely removing substrates from the sensor area. Previously, improper removal disrupted the sensor-triggered unloader mechanism.

c) Inspection Method Redesign:

A re-inspection method post-R20 inspection was introduced to eliminate scratch marks caused by manual errors. Additionally, a one-point lesson (OPL) was developed to standardize proper inspection techniques and minimize external force application. Ergonomic considerations were also included to reduce operator fatigue and error (Womack & Jones, 2003).

2.5 Control

A control plan was deployed to monitor NG rates and ensure compliance with the new procedures. Regular audits and feedback loops were also initiated to sustain improvements and prevent regression. Using the Control phase of DMAIC ensures sustainability of gains (Pyzdek & Keller, 2018; Sokovic et al., 2010).

3.0 RESULTS AND DISCUSSION

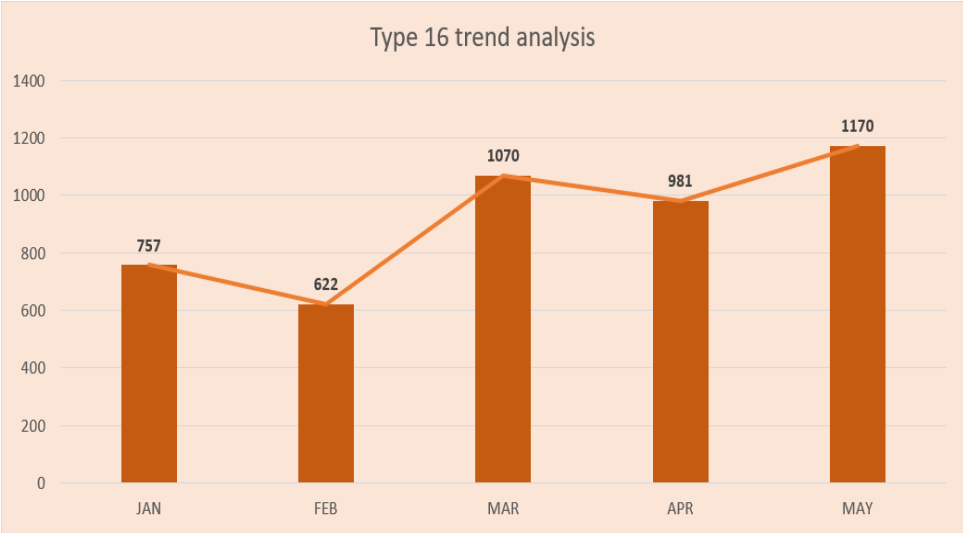
This section presents the results obtained from the implementation of the improvement actions designed during the Improve phase of the DMAIC cycle. It compares baseline data from before the intervention with performance indicators collected afterward. The analysis focuses on NG counts from taping and R20 inspection processes, validation of root causes, and assessment of the effectiveness of each implemented solution. Visual aids such as tables, line graphs, and defect trend charts are used to support the interpretation of findings.

3.1 NG Data

One of the primary performance indicators was the number of NG (non-good) pieces identified during the marking process. Prior to improvement, the average monthly NG count for Type 16 products was 920 units. Post-improvement data from September to December 2024 revealed a significant reduction, averaging 557 units.

Table 1: Scratch of Mark Defects in Type16 Products (NG Analysis)

	JAN	FEB	MAR	APR	MAY
Scratch of mark NG Pcs	757	622	1070	981	1170



MONTH	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
NG PCS	757	622	1070	981	1170	866	1076	1431	620	538	540	532

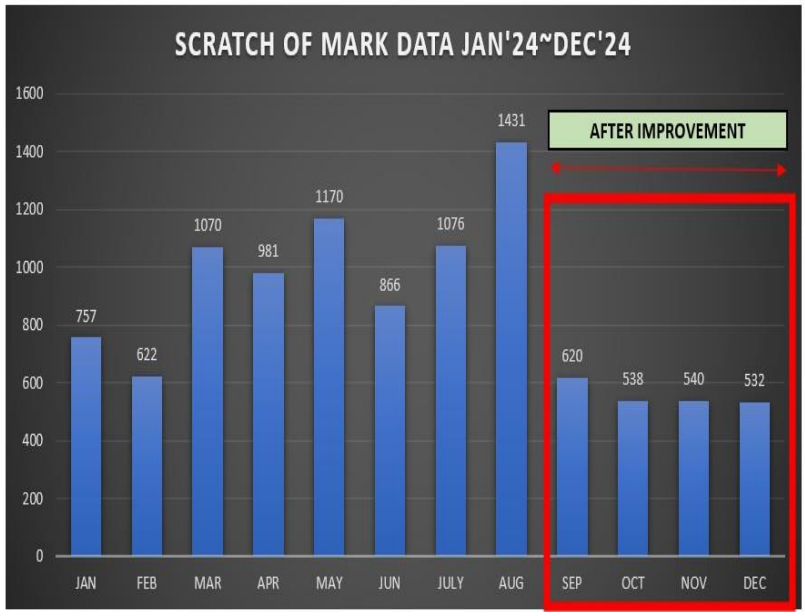


Figure 2: Defect Rate Trend – Before and After Improvements

The reduction in scratch mark defects indicates the effectiveness of process modifications. Notably, adjusting the paste ratio and standardizing handling and inspection practices contributed most significantly to this reduction.

These findings are consistent with prior studies emphasizing the importance of ergonomic process design and material compatibility in minimizing surface defects in electronics manufacturing

3.2 Interpretation of Findings

The root causes were multifactorial, involving both human and material factors. The marking paste's viscosity played a critical role, as did operator interactions with sensitive substrates. Addressing these with experimental validation and procedural standardization ensured reliable improvements.

The results affirm the value of a holistic DMAIC approach in resolving complex quality issues (Pyzdek & Keller, 2018; Antony, 2014). Moreover, the creation of easily replicable standard operating procedures facilitates knowledge transfer across teams (Mammers, 2011).

4.0 CONCLUSION

This study effectively utilized the DMAIC methodology to reduce scratch mark defects in Type16 products at Factory A Key outcomes included:

- Identification of unsuitable paste ratio and procedural lapses as major root causes
- Implementation of a revised paste ratio (90:10) with validated hardness testing

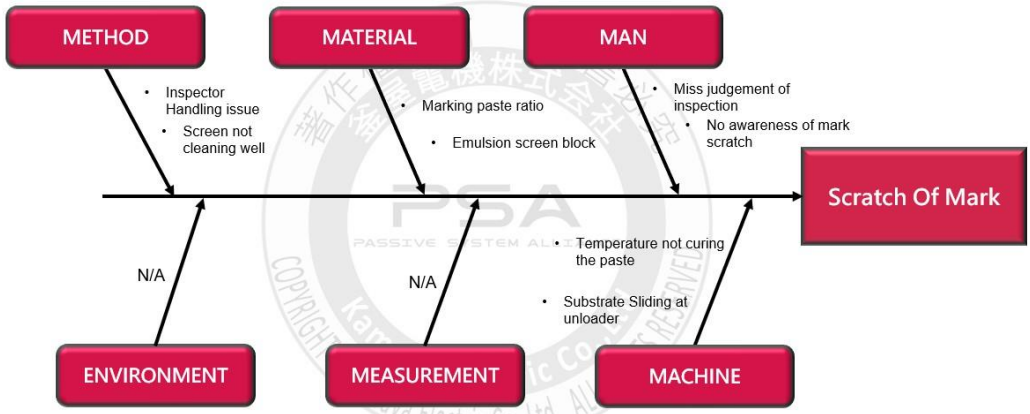
- Introduction of improved substrate handling and inspection procedures · 34% reduction in scratch mark NG rate within four months

These results not only improve production yield and customer satisfaction but also showcase how structured problem-solving can drive continuous quality improvement in manufacturing settings. Future research can explore automation of the inspection process and real-time paste quality monitoring.

APPENDIX

Appendix A: Fishbone Diagram

Appendix B: Substrate Hardness Testing Method



This model is used to test the marking hardness by sliding the substrate.

Appendix C: One-Point Lesson (OPL) Sample

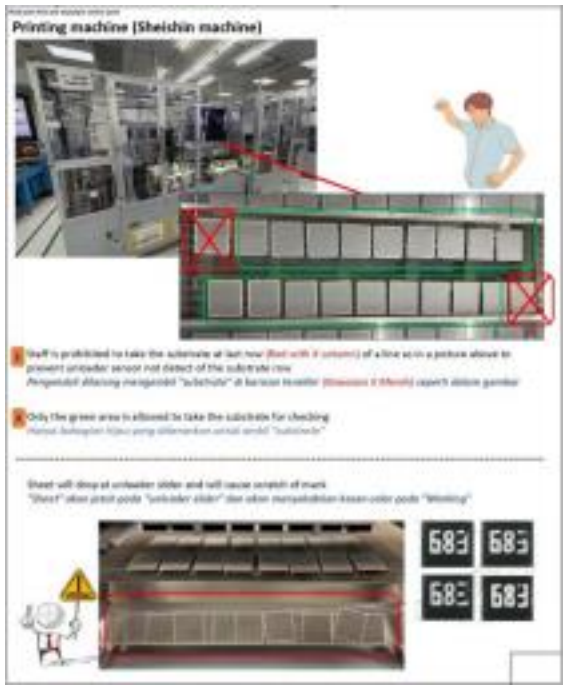


Figure 3: OPL on how to pick up the substrate

Figure 4: OPL for suitable paste ratio to used

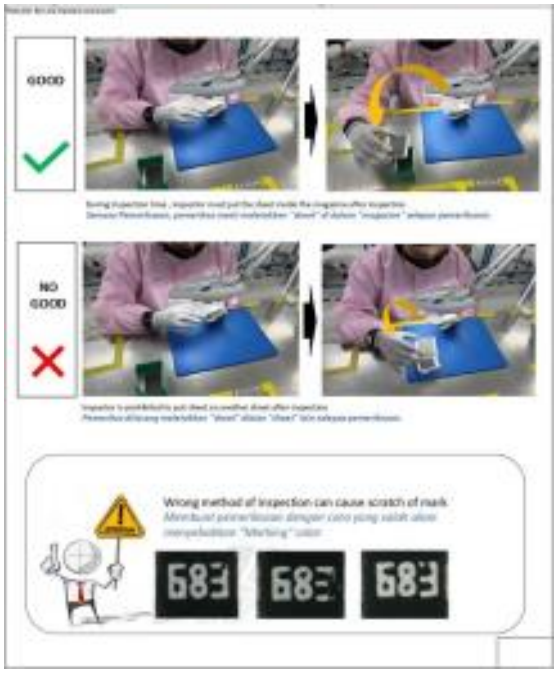


Figure 5: OPL for handling substrate

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Improvement Of Productivity At 2nd Cutting (Fix Cut)

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ABSTRACT

This project was carried out to improve the productivity of the 2nd cutting process (Fix Cut) for RLP Type 32 at a chip resistor manufacturing company. The study addresses the core issue of process inefficiency caused by inconsistent cutting performance and dimensional inaccuracy. The main objective is to enhance productivity by at least 15% using the Six Sigma DMAIC methodology. The research method involves identifying the problem through observation, measuring performance data, analyzing root causes using Fishbone Diagram and 5 Whys, implementing improvements such as standardizing procedures, and finally controlling the process with SOPs and monitoring tools. Results show that after implementing the Fix Cut method, chip dimensional accuracy improved, yield losses reduced, and productivity increased by over 40%. The study concludes that process control through DMAIC is highly effective, and these improvements contributed to increased production efficiency, reduced downtime, and lower defect rates, thus offering significant value to the electronics manufacturing industry.

Keywords: Productivity improvement, 2nd cutting process, Resistor Layer Printing (RLP), DMAIC methodology, Fix Cut

1.0 INTRODUCTION

1.0 Introduction

Established producer of chip resistors, Company X is a necessary part for contemporary electronics. Maintaining high production rates while guaranteeing constant quality is absolutely vital in the competitive manufacturing scene of today. Among the several phases of resistor manufacture, the second cutting operation in the Resistor Layer Printing (RLP) line is absolutely essential for the dimensional correctness of the end result. High accuracy is needed in this stage of cutting printed metal plate strips into individual chips to guarantee product conformance and efficiency in downstream operations including taping and inspection. This work uses the Six Sigma DMAIC technique, a disciplined problem solving tool generally acknowledged for its efficiency in enhancing manufacturing performance, to solve process inefficiencies in the RLP Type 32 line. De Mast and Lokkerbol (2012) say DMAIC helps companies find the underlying reasons of variance, create and apply focused solutions, and keep changes over time. This approach fits very nicely with the objectives of this project: to pinpoint the main causes of cutting process inefficiencies and apply environmentally friendly changes.

Previous research shows that DMAIC applied in production environments produces observable changes. By reducing faults and removing non value added processes, the adoption of DMAIC in a manufacturing line resulted in notable improvements in both quality and throughput according to Chandel and Kumar (2016). Inspired by such results, this work attempts to apply the same ideas to increase output in the second cutting process for RLP Type 32 chip resistors.

1.1 Problem Statement

The second cutting stage in the RLP Type 32 production line at Company X has experienced ongoing operational challenges. These include dimensional inconsistencies, frequent blade wear, machine downtime, and operator-dependent variability. Despite the addition of manpower and extended working hours, productivity has remained stagnant. As Booth and Zemmel (2004) emphasize, sustainable productivity growth requires more than just increasing input, it demands structural process improvements and innovation.

Disorganized process setups, lack of standard operating procedures (SOPs), and reliance on manual adjustments have made the cutting process unstable and inefficient. These issues have led to increased defect rates, reduced taping yield, and delays in production timelines. The company requires a practical and measurable solution to improve this bottleneck and achieve greater process control.

To solve this problem, a new cutting approach, referred to as the Fix Cut method, is proposed. This method incorporates equipment upgrades and operational standardization to eliminate the root causes of variation. The main objective of the study is to evaluate the effectiveness of this method in improving chip width accuracy, taping performance, and overall productivity using the DMAIC methodology.

1.2 Research Objectives

The objectives of this study are twofold. Firstly, it aims to identify the key factors that contribute to low productivity and poor yield outcomes in the second cutting process of RLP Type 32 chip resistors. Secondly, the study seeks to implement and assess improvements that will increase productivity by at least 15% in this process through the application of the Fix Cut method under the DMAIC framework.

2.0 METHODOLOGY

This study used the Six Sigma DMAIC methodology to investigate and resolve productivity issues in the second cutting process of RLP Type 32. The structured approach of DMAIC enabled systematic identification and elimination of inefficiencies.

2.1 DMAIC Methodology

The study followed the DMAIC framework:

i. Define: The problem was defined as low productivity and inconsistent output quality in the second cutting process. Common symptoms included frequent machine stoppages, irregular chip dimensions, and low yield.
ii. Measure: Data was collected from six production lots, three using the current cutting method and three using the fix cut method. Measurements included chip width, taping yield, and processing time.
iii. Analyse: Root cause analysis was conducted using Fishbone Diagrams and the 5 Whys technique. Key contributors included blade wear, poor machine calibration, and lack of standard operating procedures.
iv. Improve: Process improvements included introduce fix cut method, standardizing adjustment procedures, and conducting focused operator training. These changes were validated through trial runs.
v. Control: To sustain improvements, standard operating procedures (SOPs) were updated, preventive maintenance was scheduled, and a dashboard was implemented to track performance indicators weekly.

3.0 RESULTS AND DISCUSSION

The results of this study demonstrate substantial improvements in the second cutting process following implementation of the fix cut method. Key performance indicators such as chip width consistency, taping yield, and lot completion time were monitored and analysed. The study incorporated six lots of production data, three using the current method and three under the Fix Cut process, to ensure balanced comparison.

3.1 **Chip Width Consistency**

Dimensional accuracy is one of the most important factors in chip resistor quality. Using the bar cutter, operators observed frequent fluctuations in chip width, with many measurements exceeding control limits. This inconsistency led to non-conforming parts and higher rejection rates. After implementing the Fix Cut method, chip width variation drastically reduced. All values were maintained within the upper and lower specification limits. This consistency is attributed to the improved precision of the cutting by elimination of manual machine calibration. Figure 1 illustrates the difference in chip width distribution between the two methods, clearly showing the effectiveness of the Fix Cut in producing stable outputs.

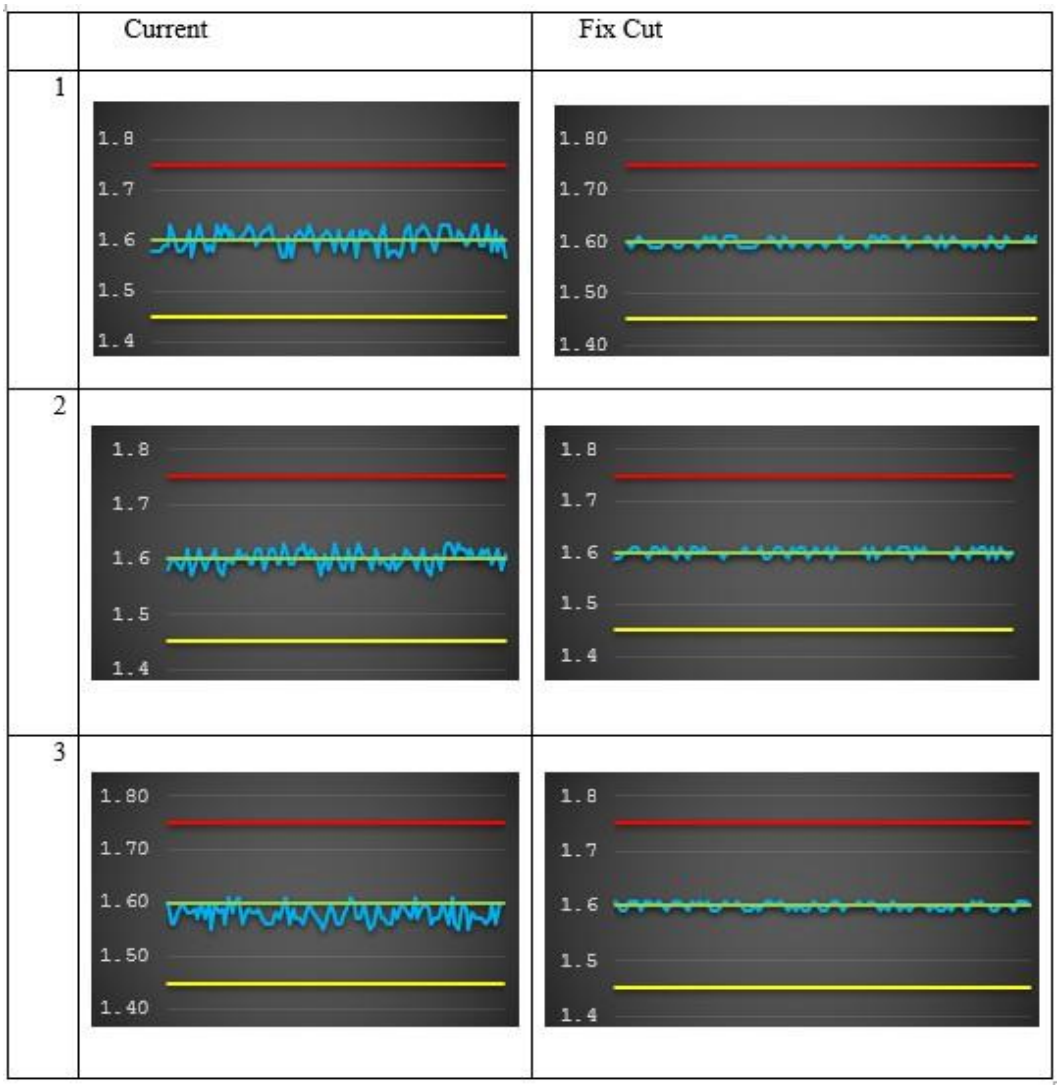


Figure 1: Chip Comparison for 100 pcs (Current vs Fix Cut)

3.2 **Graphical Comparison of Taping Performance**

The graphical representation of chip width from both the current method and the Fix Cut method, Figure 2 clearly illustrates the difference in process stability. The graphs include two critical control limits: the upper limit (red line) and the lower limit (yellow line). For the Current Method**,** the data frequently breaches both the upper and lower control limits, indicating a high level of variation and poor process control. These out of spec points suggest that many chips are being produced either too wide or too narrow, contributing to lower yield and more rework. In contrast, the Fix Cut Method shows a significantly tighter clustering of data points. All values remain within the specified control limits, demonstrating enhanced dimensional control and greater consistency. This improvement is attributed to the upgraded cutter design and the implementation of standardized machine setup procedures. This visual comparison confirms that the Fix Cut method effectively reduces variation, stabilizes output, and helps maintain quality within specification, directly supporting the observed increase in taping yield and productivity.

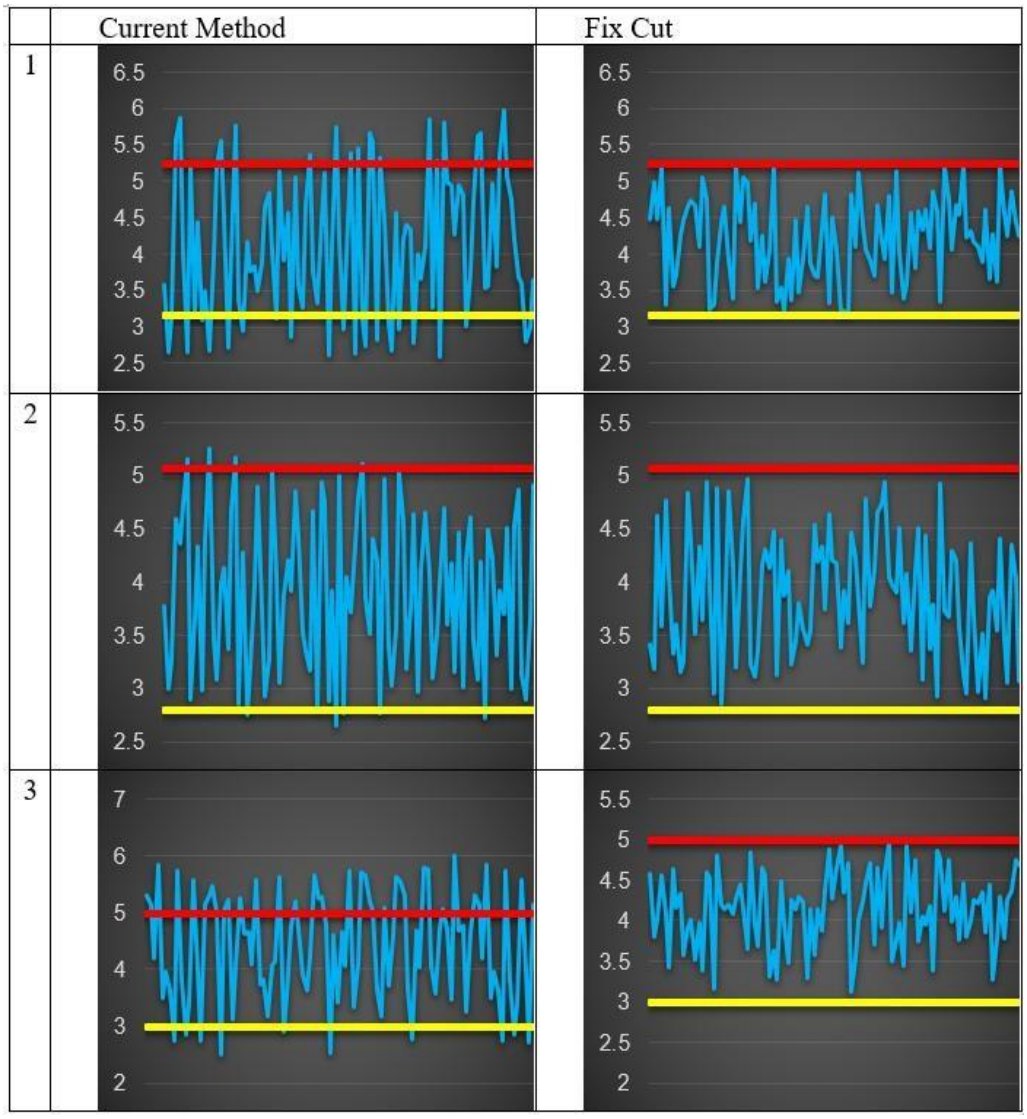


Figure 2: Resistance Values Comparison for 100 pcs (Current vs Fix Cut)

3.3 **Lot Completion Time**

Production timing data revealed that lots processed with the fix cut method were completed more quickly and with fewer interruptions. Reduced downtime due to introduce fix cut allowed for faster processing, contributing to overall productivity gains.

Table 4.3: Time Recorded to Finish 4 Lot

Lot Number	Method (Time)		Lot per Method
	Current	Fix Cut	
1	380	225	4
2	340	190	4
3	360	205	4

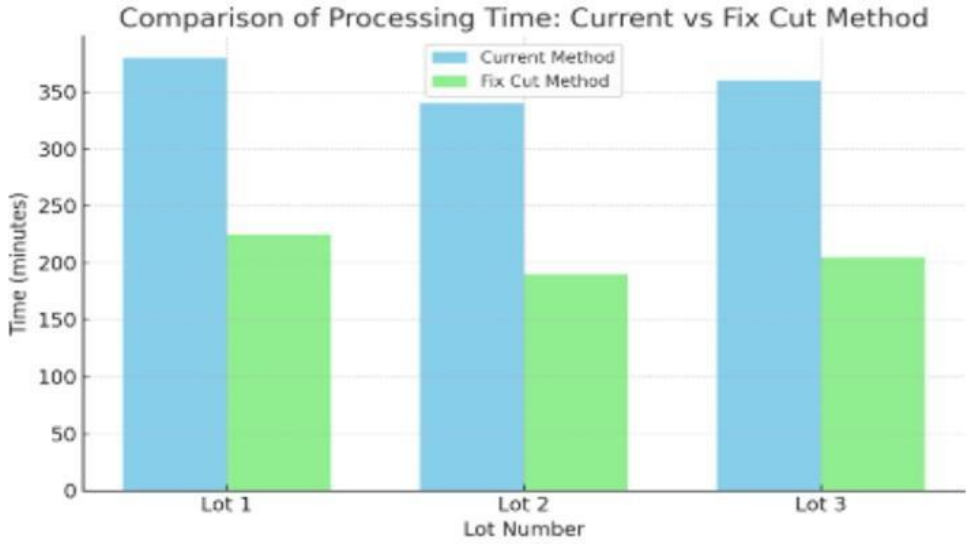


Figure 3: Time to finish 4 lot

3.4 **Summary of Findings**

All metrics evaluated showed clear improvement with the Fix Cut method. Notably:

- Over 40% increase in productivity
- Reduction in dimensional non-conformities
- Higher taping accuracy
- Shorter lot processing durations

These findings validate the hypothesis that the root causes of inefficiency could be mitigated through a structured approach. The success of the Fix Cut implementation demonstrates the value of DMAIC in driving process control and continuous improvement. Overall, the Fix Cut method provides a sustainable and replicable model for improving output quality and efficiency in precision manufacturing lines.

4.0 CONCLUSION

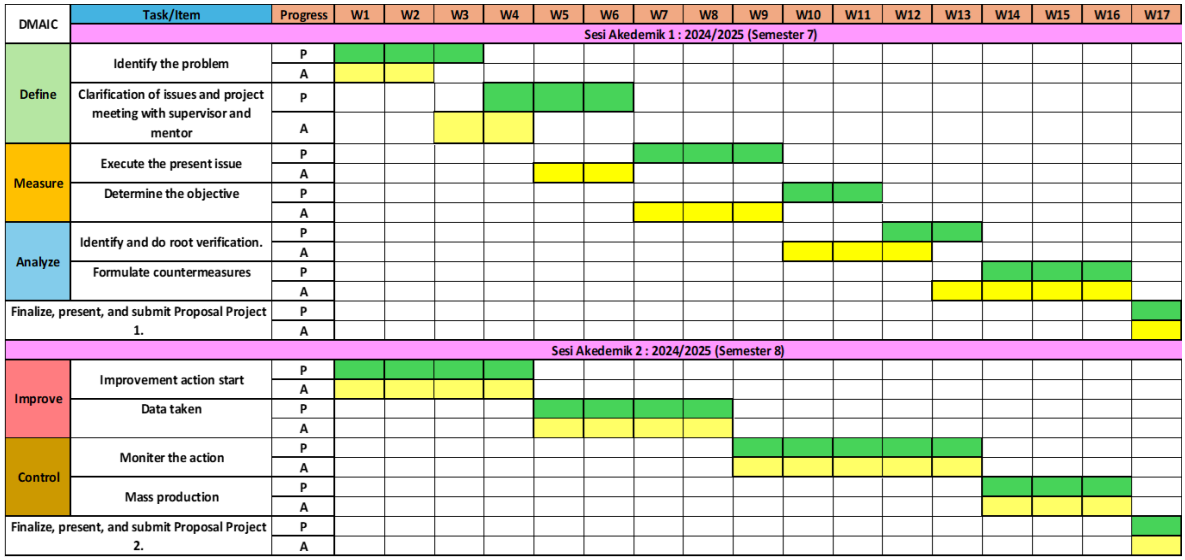
This study successfully addressed persistent productivity issues in the second cutting process of RLP Type 32 chip resistors at Kamaya Electric. By applying the DMAIC methodology,

root causes of inefficiency were identified and addressed through targeted improvements. The implementation of the fix cut method led to substantial enhancements in dimensional accuracy, yield, and production speed. These improvements not only exceeded the productivity target but also established a framework for sustaining and replicating success across other production lines.

The research highlights the importance of structured problem-solving methods such as Six Sigma in achieving measurable and sustainable improvements in manufacturing. Future studies could explore further automation of the cutting process, integration with real-time monitoring systems, and application of similar methodologies to other critical stages in resistor manufacturing.

APPENDIX

1.Gant Chart



DMAIC	Task/Item	Progress	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
Sesi Akedemik 1 : 2024/2025 (Semester 7)																			
Define	Identify the problem	P																	
		A																	
	Clarification of issues and project meeting with supervisor and mentor	P																	
		A																	
Measure	Execute the present issue	P																	
		A																	
	Determine the objective	P																	
		A																	
Analyze	Identify and do root verification.	P																	
		A																	
	Formulate countermeasures	P																	
		A																	
Finalize, present, and submit Proposal Project 1.		P																	
		A																	
Sesi Akedemik 2 : 2024/2025 (Semester 8)																			
Improve	Improvement action start	P																	
		A																	
	Data taken	P																	
		A																	
Control	Moniter the action	P																	
		A																	
	Mass production	P																	
		A																	
Finalize, present, and submit Proposal Project 2.		P																	
		A																	

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Improving Warehouse Performance via Visual Inventory Management Tools

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ABSTRACT

This study explores a warehouse improvement initiative aimed at enhancing inventory management performance through rack restructuring and the implementation of a structured labeling and stock card system. Conducted in a real operational setting, the project adopted an action research approach consisting of five phases: diagnosing, planning, acting, evaluating, and reflecting. Initial observations and interviews with warehouse staff identified several key issues, including inconsistent rack arrangements, the absence of a standardized labeling system, and missing or outdated stock records. These shortcomings led to inefficiencies in item retrieval, inaccurate inventory tracking, and overall disorganization. To address these challenges, a structured intervention was introduced. The warehouse layout was reorganized to optimize material flow, and each rack was assigned a unique identifier supported by durable, color-coded labels. Standardized stock cards were developed and placed at each storage location to record item movement and maintain real-time stock visibility. Staff were trained on how to use the new system effectively. Post-implementation results showed a 20% reduction in average item retrieval time, along with improved inventory accuracy and staff confidence. The outcomes demonstrate that simple, low-cost visual management tools, when combined with employee involvement and structured planning, can lead to significant improvements in warehouse operations and inventory control.

Keywords: Warehouse Optimization, Rack Labeling, Stock Card, Inventory Management

1.0 INTRODUCTION

Effective inventory management plays a critical role in ensuring smooth operations within warehouse environments, particularly in manufacturing and supply chain-driven industries. Warehouses function as the backbone of logistical operations by managing the flow, storage, and retrieval of goods. As such, inefficiencies in inventory handling can lead to significant disruptions, including delays in order fulfillment, increased operational costs, and diminished customer satisfaction (Low et al., 2024). A well-structured inventory system contributes not only to better product visibility and traceability but also to overall organizational efficiency and decision-making capabilities. One of the fundamental components of inventory management is the implementation of visual management tools, such as rack labeling systems and stock cards. Rack labeling allows workers to locate items quickly by providing clear visual indicators of item positions within a structured storage layout. Stock cards, on the other hand, serve as transaction records that provide real-time documentation of stock levels, movements, and REFERENCES details such as part numbers and purchase orders. These tools collectively support organized storage, faster retrieval, and improved stock tracking minimizing errors and facilitating more accurate audits (Ong Zhi Le, 2024).

However, in practice, many warehouses especially in small- and medium-sized enterprises (SMEs) lack the formalized implementation of such systems (Malek Khoffi, 2021). Inventory items may be stored arbitrarily without clear identifiers, and record-keeping may rely on manual processes or informal knowledge among warehouse staff. These limitations often lead to prolonged search times, misplaced items, inventory mismatches, and inefficient restocking

(Ogra & Ogra, 2024). Furthermore, the absence of standardized practices can complicate onboarding of new employees and contribute to long-term operational inconsistencies.

Recognizing these challenges, the focus on warehouse improvement initiatives has become increasingly important. Warehouse improvement refers to the strategic enhancement of storage layout, operational procedures, and information flow within warehouse facilities. Key areas of focus often include space optimization, inventory visibility, error reduction, and retrieval efficiency. Simple yet impactful modifications such as reconfiguring racking systems, applying consistent labelling, digitizing inventory logs, and training personnel can result in substantial productivity gains (Al Tera et al., 2024). For instance, restructured rack arrangements can reduce walking distance and item search time, while visual labelling systems improve navigation and speed up order picking processes. Moreover, improvements in warehouse operations often serve as a foundational element for broader supply chain efficiency. Efficient warehouses help reduce lead times, balance stock levels, and enhance flexibility in responding to demand fluctuations. They also support lean inventory practices by enabling better control over stock movements and minimizing unnecessary storage. Structured improvement methods such as layout reconfiguration and standard work instructions have a direct impact on worker productivity and customer satisfaction (Sookdeo, 2021).

This paper explores a warehouse improvement initiative involving the redesign of racking systems and the implementation of rack labelling and stock card documentation to enhance inventory traceability and retrieval speed. The initiative aims to solve practical, on the-ground issues faced by warehouse staff and to establish sustainable practices that enhance day-to-day operational efficiency. By focusing on low-cost, high-impact visual systems, this study provides insights into how physical layout improvements and standardized documentation can collectively transform warehouse performance.

2.0 METHODOLOGY

This study employed an action research methodology, which is well-suited for practical problem-solving within organizational settings. Action research is an iterative, collaborative process involving cycles of diagnosing, planning, acting, evaluating, and reflecting (Alfaro Tanco et al., 2021).It enables researchers and practitioners to work together in identifying problems, implementing changes, and evaluating their effectiveness in real time. This methodology was chosen to allow active participation of warehouse staff in improving their own operational environment, particularly in the area of inventory management.

Based on Figure 1, The research adopted a five-stage action research cycle comprising diagnosing, planning, acting, evaluating, and reflecting. In the diagnosing phase, existing inventory issues such as the absence of labelling, inconsistent stock records, and disorganized rack arrangements were identified through on-site observations and staff interviews. During the planning phase, targeted interventions were designed, including rack restructuring, the development of a systematic labelling system, and the creation of standardized stock card templates. The acting phase involved implementing these improvements within the warehouse environment, followed by the evaluating phase, where performance metrics such as item retrieval time were measured to assess the impact of the changes. Finally, in the reflecting phase, feedback from warehouse personnel was gathered to refine the system and ensure its practicality and sustainability. This structured approach ensured that the implemented solutions were both effective and well-integrated into daily operations.

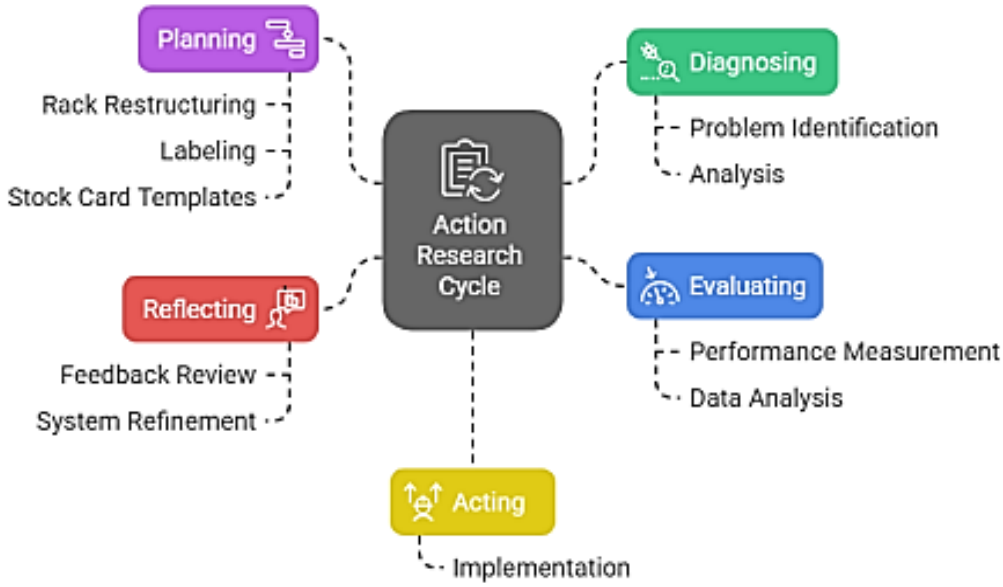

Figure 1: Action Research Cycle for Inventory Management

Three primary methods were employed to collect data during the project: observation, interviews, and time study. Initial on-site observations were conducted to assess the existing warehouse layout, storage practices, and retrieval processes, revealing baseline issues such as the absence of labelling, inconsistent stock records, and disorganized item placement. Semi structured interviews with warehouse staff and supervisors provided qualitative insights into daily operational challenges, improvement suggestions, and feedback following the implementation. To quantitatively evaluate the effectiveness of the intervention, a time-motion study was performed before and after the system changes, measuring the time taken to locate individual items, retrieve multiple items, and complete full orders. These combined methods ensured a comprehensive understanding of the existing problems and provided reliable data to assess the impact of the implemented improvements (Hamed Taherdoost, 2021).

3.0 RESULT AND DISCUSSION

3.1 Diagnosing the problems

To address the underlying causes of inefficiencies in item retrieval and poor inventory visibility, the 5 Whys methodology was applied as shown in Table 1. This technique involves repeatedly asking "why" to drill down from surface-level symptoms to the root causes of a problem. It is particularly useful in warehouse operations where recurring issues, such as misplaced items or prolonged search times, often stem from systemic flaws rather than isolated incidents. The analysis below explores the root causes of difficulty in locating items in the warehouse, a core issue observed during the diagnostic phase of this study. The first "why" identified that items were difficult to locate due to unclear or inconsistent labelling on racks. Upon further examination, it was revealed that no standardized labelling system was in place, meaning that identifiers varied in format, placement, or were entirely absent. This inconsistency created confusion for warehouse staff and led to delays in retrieval.

Continuing the inquiry, the third "why" found that employees were not trained on a consistent labelling method, and no formal guidelines or SOPs had been established. Without proper

instruction or documentation, labelling practices varied widely among staff, leading to disorganization over time. The fourth "why" uncovered that this lack of structure resulted from the absence of a dedicated process or emphasis on labelling within the broader inventory management strategy. Labelling had not been treated as a core component of the inventory control system. Ultimately, the fifth "why" revealed the root cause: inventory management practices in the warehouse had not been adequately optimized, and visual tools such as labelling were considered a low operational priority. This systemic oversight led to inconsistent execution of daily warehouse activities and compromised inventory accuracy and efficiency. By identifying this root cause, the study was able to justify a targeted intervention focused not only on rack labelling and stock card usage, but also on the development of SOPs and structured training for warehouse personnel. The 5 Whys analysis thus played a critical role in ensuring that the solution addressed foundational weaknesses rather than superficial symptoms.

Table 1: Root Cause Analysis Using the 5 Whys Method

No.	Why Question	Answer
1	Why are items often difficult to locate in the warehouse?	Because the labelling on the racks is unclear or inconsistent.
2	Why is the labelling unclear or inconsistent?	Because there is no standardized system for labelling racks.
3	Why is there no standardized labelling system?	Because staff were not trained on a consistent labelling method, and no formal guidelines exist.
4	Why were staff not trained and no guidelines established?	Because there was no structured process or focus on labelling as part of the warehouse's inventory strategy.
5	Why was there no structured process or focus on labelling?	Because inventory management practices were not properly optimized, and labelling was considered low priority.

3.2 Planning phase

During the planning phase, careful attention was given to the design of a racking layout that would support effective labelling and improve overall warehouse organization. This stage focused on strategically arranging storage racks to maximize space utilization, ensure smooth material handling, and facilitate easier access for both labelling and stock retrieval. The layout planning considered several key factors, including the dimensions and types of items stored, the frequency of item movement, and existing physical limitations within the warehouse. By segmenting the storage area according to item categories and usage patterns, the new layout enabled a more systematic labelling approach. Each rack and shelf location were assigned a unique identifier aligned with the labelling system, enhancing traceability and minimizing the risk of item misplacement as shown in Figure 2. This structured approach laid the foundation for improved visibility, faster inventory access, and more accurate stock control in subsequent phases.

Effective label design and material selection play a vital role in maintaining an organized and efficient warehouse or storage system (Mohamud et al., 2023). Labels for racks and bins should be clear, durable, and easy to read from a distance to support accurate identification and streamline operations. It is important to use high-quality, long-lasting materials that can withstand environmental conditions such as dust, moisture, and temperature changes. Standardized fonts and colours should be used consistently across all labels to ensure uniformity, improve visibility, and reduce the likelihood of errors during picking, stocking, or inventory management processes. The use of color-coding can further enhance efficiency by allowing quick identification of product categories or storage zones. Proper label placement is also essential to ensure that information is readily visible without obstructing access. By implementing a thoughtful and standardized approach to label design and material selection, organizations can significantly improve workflow, accuracy, and overall productivity in their operations.

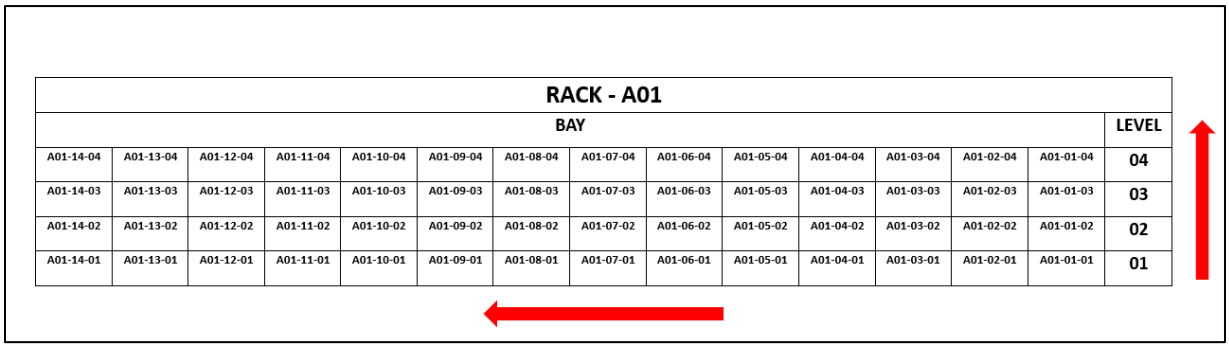

Figure 2: Racking layout

The next step in the project is to compile a comprehensive and accurate list of all items currently stored in the warehouse. This process involves physically identifying and recording every item, along with key details such as Part Number, Purchase Order number, units of measure (pieces, dimensions, weight), and the current stock levels. It is essential to ensure that all data is consistent, up to date, and correctly reflects what is actually available in storage. This inventory list as shown in Figure 3, serves as the foundation for the stock card system and labelling process, as it provides the necessary information to create accurate labels and track stock movement. Special attention should be given to verifying item details during this stage to avoid discrepancies that could impact future stock control. By establishing a clear and detailed item list, the warehouse team will be better equipped to implement an organized and efficient labelling and tracking system.

Part No.	Qty pallet	Quantity	Total	PO No.	Remarks	Date	Outgoing	Dimension (mm) - (L x W x H)			weight (kg)
								Length (L)	Width (W)	Height (H)	
83-09-6565	2	400 pcs	840.00	PO6588850	11-3783446	9/3/2025		1250	780	990	943
83-09-6565	1	40 pcs		PO6588850	11-3783446	9/3/2025		-	-	-	93
83-09-6565	2	400 pcs	840.00	PO6588885	11-3783470	9/3/2025		1250	780	990	943
83-09-6565	1	40 pcs		PO6588885	11-3783470	9/3/2025		-	-	-	93
83-09-6567	1	400 pcs	420.00	PO6588850	11-3783446	9/3/2025		1250	780	960	595
83-09-6567	1	20 pcs		PO6588850	11-3783446	9/3/2025		-	-	-	29
83-09-6567	1	400 pcs	420.00	PO6588885	11-3783470	9/3/2025		1250	780	960	595
83-09-6567	1	20 pcs		PO6588885	11-3783470	9/3/2025		-	-	-	29
83-03-4641	1	1114 pcs	1,114.00	PO6638156	1-3841896	9/3/2025		1170	770	740	371
72-00-0196	2	750 pcs	1,710.00	PO6542939	14-3772549	9/3/2025		1250	1150	930	491.3
72-00-0196	1	210 pcs		PO6542939	14-3772549	9/3/2025		1250	770	440	154
83-00-3501	5	400 pcs	2,200.00	PO6583086	14-3805444	9/3/2025		1250	1080	1150	554
83-00-3501	1	200 pcs		PO6583086	14-3805444	9/3/2025		1250	1080	650	292
72-00-0167	5	400 pcs	2,112.00	PO6539696	14-3771533	9/3/2025		1250	1080	1150	554
72-00-0167	1	112 pcs		PO6539696	14-3771533	9/3/2025		1250	1080	640	176.72
						9/3/2025					0
72-00-0026	1	3200 pcs	3,896.00	PO6542939	14-3772549	9/3/2025		1250	1000	990	505
72-00-0026	1	786 pcs		PO6542939	14-3772549	9/3/2025		1250	1140	1020	544.76
72-00-0026	1	3200 pcs	5,055.00	PO6539696	14-3771533	9/3/2025		1250	1000	990	505
72-00-0026	1	1855 pcs		PO6539696	14-3771533	9/3/2025		1000	640	1100	288.25
83-13-6678	1	2937 pcs	2,937.00	PO6595037	11-3798222	9/3/2025		1530	1180	910	767.748
83-13-6678	1	2937 pcs	2,937.00	PO6594191	11-3798220	9/3/2025		1530	1180	910	767.748
83-08-7279	1	630 pcs	630.00	PO6588885	11-3783470	9/3/2025		1250	950	800	604.6
83-08-7279	1	630 pcs	630.00	PO6588850	11-3783446	9/3/2025		1250	950	800	604.6
83-31-4247	6	400 pcs	2,574.00	PO6607321	11-3798231	9/3/2025		1250	1140	1150	607
83-31-4247	1	354 pcs		PO6607321	11-3798231	9/3/2025		1250	1140	1040	541
72-00-0167	1	400 pcs	400.00	PO6542939	14-3772549	9/3/2025		1250	1080	1150	554

Figure 3: The inventory list

Creating a standardized stock card format also essential for maintaining accurate and consistent inventory records in the warehouse. The stock card should be designed to include all critical information needed for tracking item movement and storage details. Key fields must include the part number, which uniquely identifies each item; the location, indicating the specific rack or bin where the item is stored; and the PO number (Purchase Order number), which links the stock entry to its source or procurement REFERENCES. Additionally, the card should have columns for recording quantity in and quantity out, along with dates and signatures, to monitor stock movement and maintain accountability. This standardized format ensures that all warehouse personnel follow the same system when updating inventory, reducing errors and improving traceability (Ong Zhi Le, 2024). By using a clear, consistent layout, the stock card becomes a reliable tool for day-to-day stock control and supports better decision-making in warehouse management.

3.3 Acting phase

To ensure efficient inventory management and proper organization within the storage area, it is essential to print the necessary stock cards and labels in accordance with the item and rack layout. Each item must be clearly identified with a stock card that includes important details such as item code, description, quantity, and location. Similarly, labels should be printed and attached accurately to both the items and their respective storage racks. This process helps prevent confusion, minimizes errors during stock-taking, and improves overall traceability. Before printing, verify that the information for each item matches the inventory system records to avoid discrepancies. Pay close attention to the rack layout to ensure that labels are placed in the correct positions, reflecting the actual storage plan. Using clear and legible fonts on durable label materials is also recommended to withstand handling and environmental conditions. Proper labelling and documentation are crucial for smooth stock movement, easy identification, and quick retrieval. Once all stock cards and labels are printed and correctly placed, conduct a final check to confirm everything aligns with the layout and inventory plan. This step promotes accuracy and efficiency in warehouse operations.

During the acting phase, the focus was on implementing the planned improvements and equipping warehouse staff with the necessary skills to operate the new system effectively. A key component of this phase was introducing the use of stock cards and labelling as essential

tools for maintaining inventory accuracy and operational efficiency. Stock cards serve as physical records that document item movement in and out of storage, including details such as part numbers, quantities, and purchase order REFERENCES. Their purpose is to provide real-time visibility of stock levels, which is critical for preventing shortages, overstocking, and discrepancies during audits. Accuracy and timely updates are essential, as outdated or incomplete records can lead to significant disruptions in warehouse operations (Vivek Prasanna Prabu, 2021).

To ensure proper usage, staff underwent stock card training, which included demonstrations on how to correctly fill in stock cards, with an emphasis on maintaining clear and legible handwriting. The stock card used for this training as shown in Figure 4. The training highlighted the importance of updating the stock card each time inventory is moved or adjusted. Role-play exercises were incorporated to provide hands-on practice in real-life scenarios. In parallel, a labelling system training session was conducted to familiarize staff with the new rack identification structure. This included explanations of the labelling format, demonstrations on how to read and interpret the codes, and guidance on printing and applying labels correctly. Staff were instructed on the importance of placing labels in visible and consistent positions to ensure durability and ease of use.

LEVEL : 02 (MARCH)

NO	LOCATION	PART NUMBER	PO NUMBER	QUANTITY	IN	OUT	REMARK
1	A01-01-02	83-00-4428	-	800pcs	✓	✓	
2	A01-03-02	83-13-5627	-	320pcs	✓	✓	ROBOT
3	A01-05-02	8475	-	250pcs	✓		
4	A01-02-02	4641	-	200	✓	✓	
5	A01-09-02	89-09-5601	-	1200	✓		
6	A01-08-02	9092	-	200	✓		
7	01-07-02	83-05-1805	-	1200	✓		
8	01-04-02	8923	-	14	✓	✓	ROTI
9	01-10-02	5137	-	240	✓		
10	A01-06-02	83-13-8498	-	840PS	✓		
11	A01-11-02	5627	-	320pcs	✓	✓	
12	01-11-02	5627	-	320pcs	✓	✓	
13	01-11-02	5627	-	320pcs	✓	✓	
14	01-11-02	5627	-	320pcs	✓	✓	
15	01-11-02	5627	-	320pcs	✓		
16	01-05-02	8475	-	250pcs	✓		
17	01-05-02	8475	-	250pcs	✓		
18	01-05-02	8475	-	250pcs	✓		
19	01-05-02	8475	-	180pcs	✓	✓	LOOSE
20	01-02-02	4641	-	200pcs	✓	✓	

Figure 4: Stock card

To reinforce learning, a practical application session allowed staff to actively update stock cards and apply labels on actual inventory. Supervisors monitored the activity closely, offering immediate feedback and correcting any mistakes in the process. This hands-on approach ensured that all personnel were confident in using the system correctly and consistently, thereby promoting a smooth transition to the improved inventory management process.

3.4 Evaluating and reflecting phase

The time study conducted as part of this warehouse improvement project as shown in Table 2, provides compelling technical evidence of the operational benefits gained from implementing structured rack labelling and stock card systems. Prior to the intervention, the warehouse lacked a standardized system for item identification and tracking. Items were stored

without logical sequence, and workers relied heavily on experience or verbal communication to locate stock. This resulted in excessive time spent searching for items, which not only delayed order processing but also disrupted the overall workflow and increased labour inefficiencies. Technically, the initial retrieval process lacked spatial orientation and visual guidance. With racks unlabelled and no dedicated storage zones, the probability of redundant movements and backtracking was high. This contributed to prolonged search paths, unoptimized picking sequences, and increased cognitive load for workers during high-demand periods. Additionally, the absence of real-time stock records meant that even when items were physically located, verification and quantity confirmation often required additional manual checking or intervention from supervisors.

Table 2: Time study

Description	Before Implementation	After Implementation	Time Saved	% Reduction
Average time to locate 1 item	6 minutes	4 minutes	2 minutes	20%
Time to locate 10 items	60 minutes	40 minutes	20 minutes	20%
Time to complete 1 order	60 minutes	40 minutes	20 minutes	20%

Following the implementation, the introduction of unique rack identifiers and color-coded labels created a systematic, visually guided navigation system within the warehouse. Each rack location was assigned a code that corresponded with stock card entries, allowing workers to quickly identify, access, and verify the required items. This spatial restructuring of storage zones transformed the picking process into a more predictable and linear flow, minimizing unnecessary walking distance and time spent per task.

Furthermore, stock cards placed at each rack location served as static information hubs, enabling instant verification of part numbers, quantities, and recent transactions. These cards reduced the need for back-and-forth communication or manual database checks, leading to faster decision-making and higher process reliability. Quantitatively, the impact was evident: the time to retrieve a single item dropped from 6 minutes to 4 minutes, while locating 10 items or completing an entire order saw consistent improvements of 20 minutes per cycle, amounting to a 20% efficiency gain. This performance boost directly translates into reduced labour hours per order, improved order throughput, and greater capacity for high-volume operations demonstrating the technical and operational value of structured inventory systems in warehouse environments.

Table 3: The results of the interviews

Interview Question	Summary of Response
1. What are the current practices and challenges in the inventory management system?	Manual stock cards and basic barcode systems were used; however, inconsistent labelling and missing records made it hard to locate items and caused stock inaccuracies.
2. How can a structured inventory system improve the process of locating items?	A structured system with clear labelling and proper stock placement would reduce search time, improve accuracy, and allow even new staff to find items easily.
3. What features or practices can reduce time wasted in locating items?	Use of color-coded and standardized labels, organized storage based on item frequency, real-time stock card updates, staff training, and clear signage or layout maps.
4. What are the consequences of poor labelling on warehouse racks?	Poor labelling leads to picking errors, misplaced items, longer search times, delayed fulfilment, and overall inefficiency in warehouse operations.

Interviews with warehouse personnel were conducted to gain a deeper understanding of the existing inventory management challenges and to assess the potential effectiveness of implementing a structured rack labelling and stock card system. These interviews served as a critical part of the diagnosing phase, providing first-hand insights from employees directly involved in daily warehouse operations. The information gathered not only validated the issues observed during on-site assessments but also helped guide the planning and design of the new system to ensure its practicality and relevance. The results of the interviews are summarized in Table 3.

Respondents believed that a structured inventory system would greatly enhance efficiency, particularly in locating items more quickly and accurately. They highlighted that clear rack labelling, systematic item placement, and real-time inventory records would streamline daily operations and reduce reliance on experienced workers. Additionally, a formalized system would simplify the training process for new staff, making it easier for them to adapt to warehouse procedures. To further improve efficiency, workers suggested incorporating standardized, colour coded rack labels, organizing inventory based on frequency of use or item type, and maintaining accurate stock cards. They also emphasized the importance of staff training on recordkeeping and label usage, as well as the inclusion of visual guides or maps to support item identification. Interviewees noted that unclear or missing labels previously led to significant operational issues such as picking errors, extended search times, delayed order processing, and frustration among workers factors that collectively disrupted overall warehouse performance.

4.0 CONCLUSION

This study demonstrated that warehouse inventory performance can be significantly improved through the implementation of structured rack labelling and stock card systems. The project, conducted through an action research approach, addressed core inefficiencies such as disorganized storage, lack of standard labelling, and unreliable stock records. By reorganizing the racking layout and introducing visual management tools namely color-coded labels and standardized stock cards the warehouse achieved measurable improvements in both efficiency and accuracy. Post-implementation time studies indicated a 20% reduction in average item

retrieval time, highlighting the effectiveness of these low-cost, high-impact interventions. Additionally, interviews with warehouse staff revealed improved ease of locating items, fewer picking errors, and greater confidence in inventory accuracy. The training provided during the implementation phase empowered staff to consistently update records and follow the new system with minimal supervision. Overall, the findings confirm that visual control, proper documentation, and standardized practices are essential components of an efficient inventory management system. These improvements not only streamline daily operations but also support long-term sustainability, particularly when combined with periodic audits and continuous staff engagement. The project outcomes provide a strong case for other warehouses seeking practical and scalable solutions to enhance operational efficiency and inventory control.

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Increasing Productivity At Resistive Printing (0201)

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ABSTRACT

This project aims to Increase Productivity at Resistive Printing 0201 components by optimizing machine 77B, which integrates resistive printing directly into the firing process. The main challenge was the long wait initial testing time, which caused production delays and reduced daily output. To address this, the research proposed shifting thickness measurement from post firing to post-dryer, reducing the test duration by 20%. Key parameter inconsistencies such as squeegee speed, scraper speed, screen gap, printing pressure, and substrate-to-stage distance were analysed, leading to optimized settings for medium-value products. A root cause analysis using the Fishbone Diagram method helped categorize contributing factors, while a time study confirmed that the revised process reduced testing time from one hour to 22 minutes. The project established post-dryer thickness specifications of 8 µm – 12 µm, optimized printing parameters, and significantly improved efficiency. These enhancements streamline the resistive printing process, minimize production delays, and improve overall productivity.

Keywords: Resistive Printing 0201, Thickness Measurement, Fishbone Diagram, Time Study, Parameter Optimization

1.0 INTRODUCTION

R09 Resistive Printing is one of the key processes in producing chip resistors at Kamaya Electric. In this process, resistive paste is printed onto ceramic substrates to achieve accurate resistance values based on customer requirements. It's a process that requires precision because the thickness of the print and stability during firing directly affect the product's quality. At R09, every step needs to be carefully controlled, especially during test prints and inspections. So, if this process can be made faster and more efficient, it won't just improve productivity it also help maintain consistent product quality.

1.3 Objectives

The main objectives for this project is to reduce the test print time interval by 20%, aiming to speed up the process and reduce delays. By minimizing waiting time during the firing and thickness measurement stages, the workflow can become more efficient. This improvement is expected to boost overall productivity and efficiency in the Resistive Printing process at Kamaya Electric.

1.2 Literature Review

Resistive printing, a critical process in electronic component manufacturing, involves applying resistive ink onto substrates to create precise resistor values. Productivity in this process is often influenced by several factors including material preparation, machine calibration, operator skill, and process flow timing. One of the most common bottlenecks is the delay caused by the initial test print, which must be validated for thickness and resistance accuracy before full scale production can proceed.

Previous studies in printed electronics have shown that delays in the firing and measurement stages can significantly affect overall throughput (Lee et al., 2020). Operators typically wait for the first sample to be fired and measured before continuing with the rest of the lot, leading

to idle time and underutilization of resources (Tanaka & Ito, 2018). Automation in thickness measurement and real-time feedback systems have been suggested to mitigate these delays and improve process flow efficiency (Zhou et al., 2019). In the context of lean manufacturing, reducing wait time and improving setup efficiency are key to increasing productivity. Techniques such as SMED (Single-Minute Exchange of Die), visual controls, and real-time data monitoring have been successfully applied in similar printing processes to reduce setup time by up to 30% (Smith & Chan, 2017).

For Kamaya Electric, optimizing the resistive printing process by minimizing the interval between test print and production can not only reduce delays but also enhance consistency, product quality, and resource usage. Literature supports that targeted improvements in process timing and automation can yield significant gains in both efficiency and throughput in precision printing environments.

1.5 Problem Statement

In the current Resistive Printing process at Kamaya Electric, operators face significant delays during the initial testing stage before starting full production. They are required to run a first test print, which must undergo a firing process before the thickness can be measured. This causes the operator to wait idly, resulting in lost time and reduced efficiency. If the test fails to meet the required thickness standard, it must be repeated, further increasing the downtime. This repeated cycle creates a bottleneck that slows down the entire production line, affecting line utilization and delivery schedules. Moreover, valuable machine time is wasted, and operational costs rise due to prolonged cycle times. The absence of real-time monitoring or automated validation adds to the problem, as all steps rely heavily on manual operations. In high-volume manufacturing, such delays become even more critical, limiting responsiveness and overall output. Without a faster and more efficient test validation method, the productivity and efficiency of the Resistive Printing process remain compromised. Therefore, solving this issue is crucial to improving workflow, meeting production targets, and reducing unnecessary delays.

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2.0 METHODOLOGY

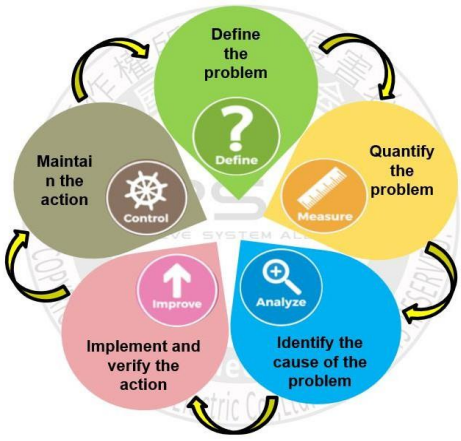


Figure 2.1 show: DMAIC Method for Continuous Improvement Process

Figure 2.1 shows the DMAIC method, which stands for Define, Measure, Analyze, Improve, and Control. This structured approach is commonly used in Six Sigma and continuous improvement projects. It starts with the Define phase, where the problem is clearly identified and project goals are set. In the Measure phase, data is collected to understand the extent of the problem. The Analyze phase focuses on identifying the root causes behind the issue. After that, the Improve phase involves implementing and verifying solutions to address the problem

effectively. Finally, the Control phase ensures that the improvements are maintained over time by monitoring the process and standardizing new practices. This cycle supports better decision making and drives long-term efficiency and productivity.

Define

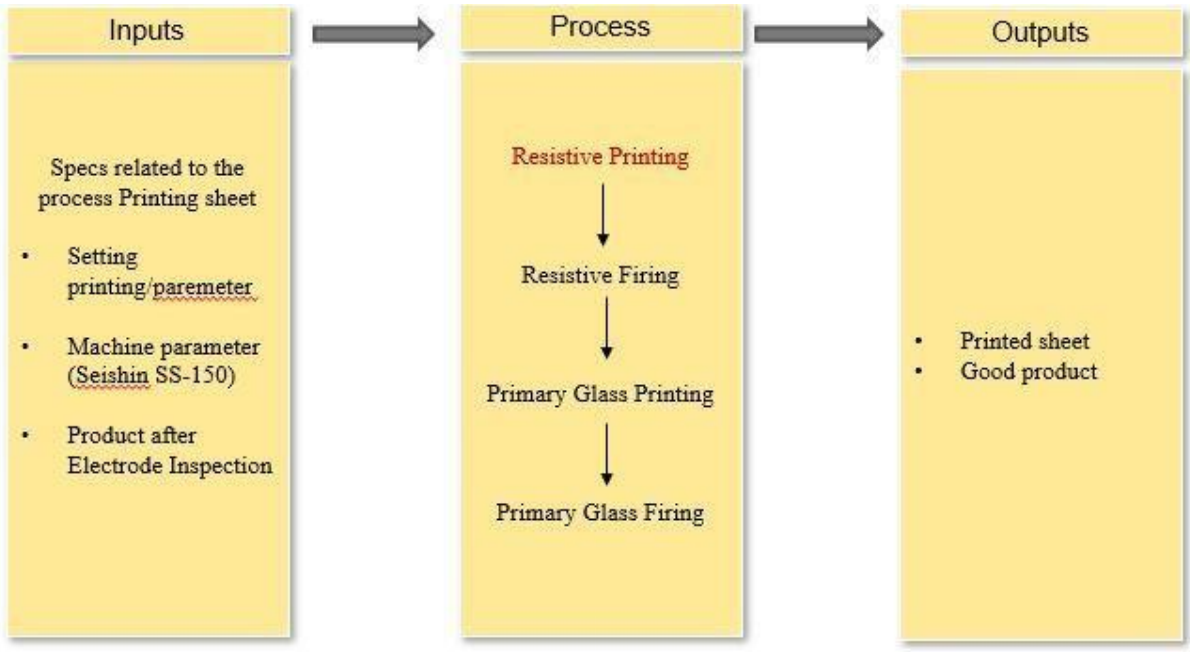


Figure 2.2 show: SIPOC Diagram

Figure 2.2 shows a SIPOC (Supplier, Input, Process, Output, Customer) diagram that outlines the key elements involved in the resistive and glass printing process, commonly used in electronic component manufacturing. This structured visual representation helps to identify the core process steps, responsible parties, and critical parameters involved in producing a quality product.

Starting with the Supplier, the input is the product that has already undergone electrode inspection, ensuring that it meets basic quality standards before entering the next stage. The Input section defines several crucial machine settings and parameters that influence process consistency and quality, including substrate-to-stage distance, screen gap, printing pressure, squeegee and scraper speeds, and return gaps. These inputs are vital for achieving the required printing performance. The Process section outlines the sequential operations beginning with Resistive Printing, followed by Resistive Firing, Primary Glass Printing, and ending with Primary Glass Firing. These steps represent a controlled workflow that builds up the necessary material layers on a substrate through precise printing and thermal treatment.

As a result, the Outputs of this process include a printed sheet with specifications conforming to desired thickness ranges (6–10 µm), and a good quality product ready for the next phase. Finally, the Customer in this context is the Primary Glass Printing stage, indicating the downstream process that receives the output from this operation. Overall, Figure 2.2 highlights the importance of controlling input parameters and maintaining process discipline to ensure consistent output quality in a manufacturing environment like Kamaya Electric (M) Sdn. Bhd.

Define:

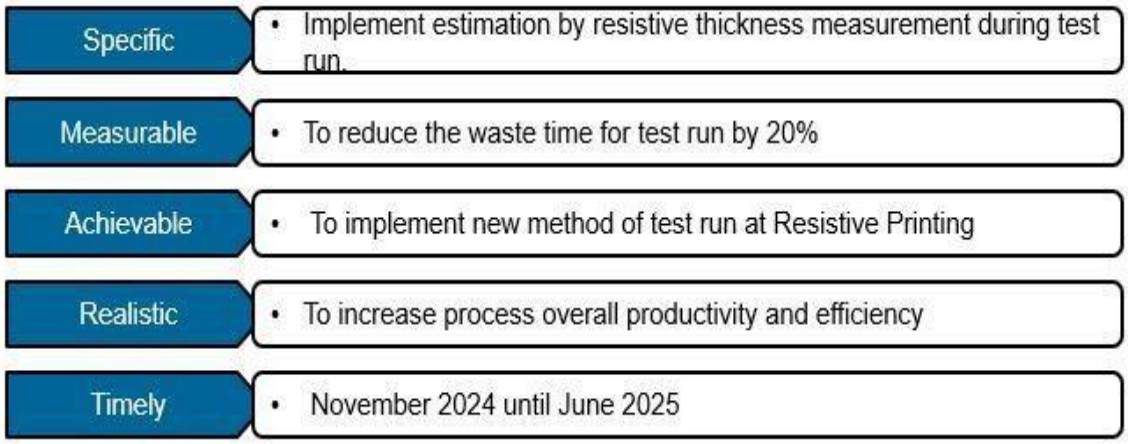


Figure 2.3 show: Target Setting

Figure 2.3 shows a target setting framework using the SMART goal approach, which stands for Specific, Measurable, Achievable, Realistic, and Timely. This method is applied to improve the test run process at the resistive printing stage by addressing waste time and enhancing efficiency.

The Specific goal is to implement estimation through resistive thickness measurement during the test run. This targets a clear and defined improvement in how test runs are assessed. The Measurable objective is to reduce waste time during test runs by 20%, allowing progress and success to be quantified. The Achievable target is to introduce a new method of test run for resistive printing, which suggests that the goal is within the team capability and resources. The Realistic aspect focuses on increasing overall process productivity and efficiency, ensuring the goal aligns with broader operational priorities. Lastly, the Timely component sets a clear time frame for implementation from November 2024 until June 2025 providing a deadline to maintain momentum and accountability. Overall, Figure 2.3 demonstrates a structured and goal-oriented plan to improve the resistive printing process through measurable and practical actions within a specified timeframe.

Measure:

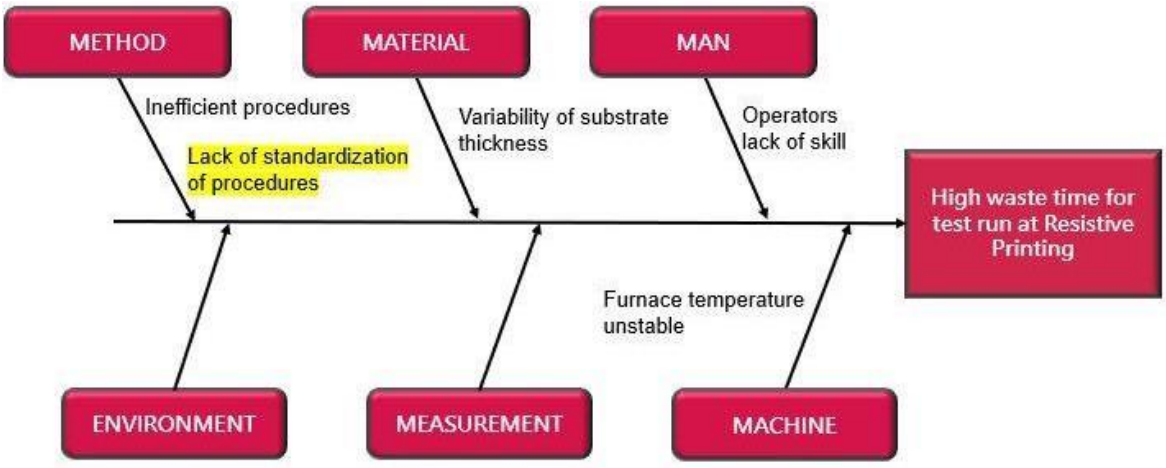


Figure 2.4 show: Ishikawa Diagram

Figure 2.4 show a fishbone diagram, also known as an Ishikawa or cause and effect diagram, used to identify the root causes contributing to high waste time during test runs at the resistive printing stage. This diagram categorizes potential causes into six main areas: Method, Material, Man, Machine, Measurement, and Environment.

Under the Method category, two major issues are identified: inefficient procedures and a lack of standardization. These procedural shortcomings can lead to inconsistencies in how the process is performed, resulting in increased trial-and-error during test runs. In the Material category, variability in substrate thickness is highlighted as a critical factor. Inconsistent substrate thickness can negatively affect printing quality and lead to rework or rejection.

The Man category refers to human factors, particularly the lack of skill among operators. Inadequate training or experience can lead to improper handling of equipment and materials, further contributing to waste. Under the Machine category, the furnace temperature is noted as unstable, which can impact the curing or firing process, leading to defective products.

Although no specific issues are listed under Environment and Measurement in the diagram, these areas are acknowledged as potential sources of variation that could influence the process. Overall, this fishbone diagram helps pinpoint the underlying causes of inefficiency, providing a foundation for corrective actions aimed at reducing waste time and improving process reliability in resistive printing.

Measures:

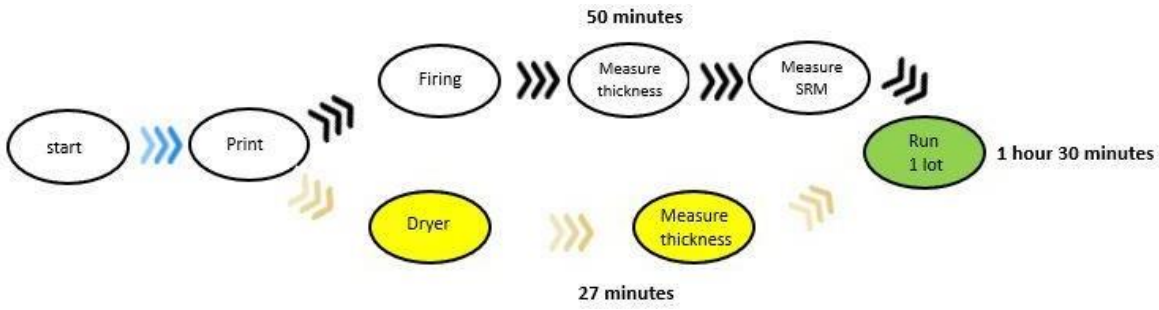


Figure 2.5 show: Critical Path Diagram

Figure 2.5 show the critical path diagram with the comparison highlights how the proposed workflow significantly improves efficiency by reducing processing time. The current method takes 50 minutes due to heating, stabilization, and cooling steps, whereas the suggested change transitioning from printing to drying instead of firing shortens the process to 22 minutes**.** This 28-minute reduction eliminates unnecessary delays, streamlining production without compromising quality. The optimized method improves resource utilization, scheduling, and consistency, ultimately accelerating production while maintaining reliability.

3.0 RESULTS AND DISCUSSION

3.1 Productivity Rate after one Test sheet

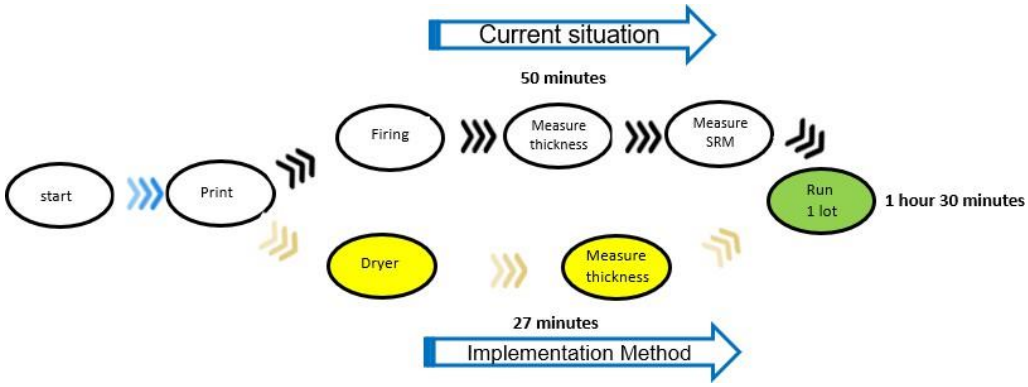


Figure 3.1 shows: The critical path diagram for the 0201 resistive printing process improvement, outlining the sequence of key tasks that directly affect the project completion timeline.

Figure 4.4.1 shows the comparison between the current workflow and the suggested implementation method, focusing on the time required for the process. In the current setup, the duration recorded after firing averages (50 minutes), which is significantly longer due to the additional steps involved in heating, stabilization, and cooling before the next stage can proceed. These factors contribute to delays in the overall production cycle, affecting efficiency and turnaround time. However, the proposed adjustment introduces a new approach, where the process transitions from printing to drying instead of firing. This modification results in a much shorter processing time, with the recorded average dropping to (22 minutes), representing a substantial improvement. The difference of (28 minutes) highlights the advantage of the new method, offering a more streamlined and efficient workflow without compromising the quality of the final output. By reducing the reliance on firing, the process eliminates unnecessary waiting periods, ensuring a quicker transition to subsequent stages. This shorter duration enables better resource utilization and production scheduling, helping to optimize cycle times while maintaining consistency. With the new approach, operations become more predictable, reducing overall lead times and improving productivity. These findings provide crucial insights into process efficiency, demonstrating how workflow adjustments can significantly enhance performance. Implementing the suggested method not only accelerates production but also ensures a more balanced and cost-effective operation, making it a practical improvement for sustaining high-quality results while meeting efficiency goals. If further refinements are necessary, additional trials can be conducted to assess any potential areas for improvement, ensuring that the optimized method continues to deliver reliable and consistent outcomes.

With the new approach, operations become more predictable, reducing overall lead times and improving productivity. These findings provide crucial insights into process efficiency, demonstrating how workflow adjustments can significantly enhance performance. Implementing the suggested method not only accelerates production but also ensures a more balanced and cost-effective operation, making it a practical improvement for sustaining high quality results while meeting efficiency goals. If further refinements are necessary, additional trials can be conducted to assess any potential areas for improvement, ensuring that the optimized method continues to deliver reliable and consistent outcomes.

The productivity rate result after implementation has reached 16.43, successfully meeting the targeted goal of reducing the test print time interval by 20%. This achievement directly contributes to an overall increase in Resistive Printing productivity and efficiency, making the printing process more streamlined and effective. By optimizing various parameters such as substrate-to-stage distance, screen gap, printing pressure, scraper speed, and squeegee speed, the newly implemented settings have significantly reduced unnecessary delays and improved workflow consistency. The shorter test print time interval enables a faster turnaround, minimizing downtime between cycles and enhancing operational output. One of the key factors contributing to this improvement is the transition from firing to drying, which has drastically cut down processing duration. Instead of waiting for the extended firing phase, substrates now undergo a more efficient drying stage, reducing overall completion time without compromising quality. This adjustment alone has led to a substantial improvement in cycle efficiency.

Current situation	**After implementation**
50 minutes + 1 hour 30 minutes = 2 hour 20 minutes	27 minutes + 1 hour 30 minutes = 1 hour 57 minutes

Productivity rate : $\frac{2\ hour\ 20\ \text{min} - 1\ hour\ 57\ min}{2\ hour\ 20\ min} = 0.1643 \times 100 = 16.43\%$ for actual

Additionally, the refined machine settings ensure greater precision in ink application, reducing errors and inconsistencies that previously affected print results. With optimized printing pressure at 2.5 kg and squeegee/scraper speed at 100 mm/s, the printing process achieves balanced ink deposition, improving overall print stability while increasing production throughput. The increase in Resistive Printing productivity means that more units can be processed within a given timeframe, helping meet higher production demands while maintaining consistent output quality. As efficiency improves, resource utilization is enhanced, reducing material waste and operational costs.

Overall, this successful implementation demonstrates that strategic adjustments to workflow and machine settings lead to substantial productivity gains. The achieved rate of 16.43 not only reflects the improvement in test print timing but also highlights the broader impact on production efficiency, quality control, and operational effectiveness. With these enhancements in place, the printing process is now more optimized, delivering higher output rates while ensuring reliability and precision in Resistive Printing.

3.2 Defining the Optimal Thickness Range for Dryer and Firing Stages

Value	Thickness after dryer	Thickness after firing (6 ~ 10µm)	SD	Yield
7502 F P1	11.625	7.355	6.54%	99.75%
222 J P1	11.935	9.64	2.86%	99.54%
2002 F P1	11.24	7.355	3.254%	99%
512 F PK	11.135	7.325	3.878%	100%
4703 F 61	9.7	7.18	3.442%	99.54%
1001 F P1	11.165	8.895	3.133%	98.62%
2002 F P1	9.22	7.45	3.449%	98.85%
2102 F P1	11	6.99	3.326%	99.03%
1103 F P1	10.18	6.795	10.765%	99.08%
104 J PK	10.115	6.795	3.841%	99.77%
202 FP1	9.4	7.345	3.181%	99.54%
4702 F P1	7.625	6.005	4.793%	99.77%
4701 F P1	11.24	7.564	3.283%	99.77%
3092 F R1	11.13	7.775	3.284%	96.79%
1002 F P1	9.745	7.725	3.766%	99.54%
2003 F P1	10.32	7.82	4.13%	99.08%
9099 F PK	11.215	7.315	3.146%	100%
2400 F 61	11.77	6.74	7.997%	97.58%
200 J P1	9.34	7.65	4.881%	99.08%
1000 F 61	10.74	6.32	4.191%	98%
3309 F PK	10.565	7.93	3.721%	99.72%

Table 3.2 shows: Data analysis of thickness after dryer and firing process.

Figure 3.2 shows the data analysis of thickness after the dryer and firing processes, which is used to determine whether the post-dryer thickness meets the required specification. For the firing process, the thickness remains within the expected range of (6 µm – 10 µm), meaning the final result still meets the required standard and doesn't deviate from the target.

From this analysis, we can see that the thickness can vary depending on the process used. After the dryer, there's usually a bit of variation because during the drying stage, many factors come into play – such as the moisture evaporation rate, material stability, and so on. However, once the material goes through the firing process, the thickness becomes more stable because the material has been fully densified under high temperatures. When we compare the thickness after drying with the thickness after firing, the change is still manageable. If the post-dryer thickness is slightly off, there's a chance the material might shrink a bit during firing. But the data shows that even with some variation, the thickness after firing still falls within the (6 µm –10 µm) range. So overall, it can be said that the process is still under control and meets specifications. After thoroughly analysing the thickness data, we successfully determined an after-dryer thickness specification range of (9 µm – 12 µm) microns. This range was selected based on the observation that when the thickness after drying falls within this range, the final result after firing tends to be more consistent and stable within the targeted (6 µm–10 µm) range.

With this insight, we can now make adjustments to ensure that the post-dryer thickness stays consistent – for example, by adjusting the drying temperature, airflow, or drying time. Once the dryer process is stable, the firing process becomes easier and the final output will be more

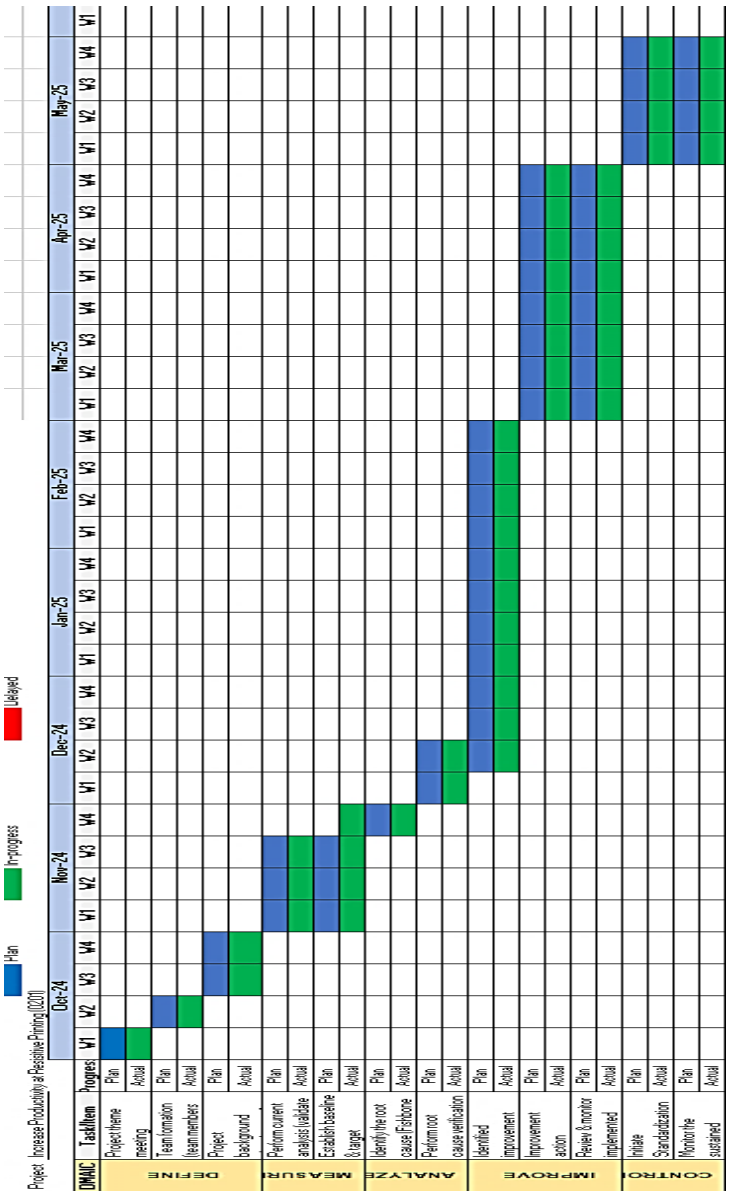
uniform. In short, monitoring the post-dryer thickness is crucial because it gives an early indication of what the final result after firing might look like. If we can stabilize things early on, the whole process will run more smoothly, and the final product quality will be more reliable.

4.0 CONCLUSION

The resistive printing process has several strengths, such as experienced operators, stable equipment like the Seishin SS-150, and a reliable firing process that helps meet thickness requirements. However, it also faces weaknesses like time-consuming test runs, manual steps, and lack of real-time monitoring. Opportunities for improvement include automating test runs, using data analytics, and upgrading systems for faster thickness checks. On the other hand, threats such as human error, equipment failure, and competition with more advanced technology could affect productivity and quality. Overall, the process is strong but still has room for improvement.

APPENDIX

1. Gantt Chart



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Integrated Approach to Store Efficiency: Layout Planning and Material Management using QR Technology

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ABSTRACT

Effective material management is essential for industries that depend on continuous equipment maintenance. This project focuses on developing an optimized floor plan and implementing a structured organizational system for the maintenance store at ABC Company. The store faced several challenges, including difficulty in locating materials due to unclear labeling, disorganized shelving, scattered items, and blocked pathways factors that led to wasted time, decreased productivity, and operational delays. The objectives of this project are to identify existing inefficiencies, design a streamlined floor layout, and evaluate the performance of racking systems, labelling methods, and QR code implementation. A mixed-methods approach was adopted, combining qualitative and quantitative techniques. The methodology involved root cause analysis using a Fishbone Diagram, followed by the development and implementation of interventions such as a redesigned store layout and a digital QR code-based inventory tracking system. Results demonstrated significant improvements, including a reduction in average retrieval time from 15 minutes to 8 minutes, an increase in employee satisfaction from 45% to 85%, improved space utilization from 60% to 90%, enhanced stock accuracy from 70% to 95%, and improved workflow efficiency from 55% to 88%. These findings offer a practical and replicable model for optimizing maintenance store operations, contributing to higher productivity, greater employee satisfaction, and reduced operational delays.

Keywords: Efficient Material Management, Floor Plan Optimization, Maintenance Store Organization, QR Code Technology, 5S Methodology.

1.0 INTRODUCTION

Successful maintenance store management is crucial to production continuity, particularly in sectors where operation uptime, equipment reliability and clean working environment are paramount. ABC company, a top producer of clean air solutions for industries such as pharmaceutical, electronics and advanced manufacturing has been hounded by chronic inefficiencies in its maintenance store. These issues occur because of unorganized storage arrangements, inadequate marking and the absence of an organized stock system which causes excessive time to retrieve, increased machine downtime and frequent workflow disruption. These inefficiencies do not just impede maintenance productivity but also employees' manner, it creates frustration, unequal work quality and inability to meet operational objectives. Thus, improving maintenance inventory management is essential to provide good performance and reliability in the firm.

This project aims to improve maintenance store efficiency by identifying existing operational issues, proposing an optimized layout with systematic zoning and standardized labelling and implementing a QR code-based digital inventory system to enhance traceability, retrieval speed, and stock accuracy. The scope of the study covers only the ABC company maintenance store operation and focuses on floor space optimization, inventory marking and material picking procedures. Procurement and supply chain consequences are outside the scope.

For solving the problems found in the study, the 5S approach Sort, Set in order, Shine,

Standardize and Sustain is employed as a functional foundation for improving workplace organization with lean manufacturing implementation. According to Arifin et.al (2022) application of 5S in manufacturing and maintenance environments has already been found to increase efficiency within the workplace, reduce waste and enhance safety. With digital solutions like QR code tagging also gaining widespread application as effective solutions for tracing and monitoring inventories in real-time. Recently, Lim and Goh (2023) and Rosli et al. (2021) point out that the integration of simple digital technologies in regular manual inventory systems can improve the accuracy of data, reduce search time and reduce level of human errors. By combining lean organizational methods with computerized inventory software, this project aims not only to enhance the efficiency of ABC company's maintenance warehouse but also to make an overall contribution to the understanding of low-cost, high-benefit inventory optimization strategies in industrial settings.

2.0 METHODOLOGY

The methodology of the project in this project was structured to apply systematic analysis and ongoing improvement principles for addressing inefficiencies in ABC Company maintenance store. The approach included root cause analysis, Lean 5S methodologies, strategic design, and digital integration of inventory via QR code implementation. Each step was thoroughly executed to make physical and procedural improvements to enhance store organization, reduce retrieval times, and maximize overall operational efficiency.

2.1 Root Cause Analysis using the Ishikawa Diagram

The Ishikawa Diagram (or Fishbone Diagram) was used for root cause analysis, graphical tool for categorizing likely causes of inefficiencies into six broad dimensions. Figure 1 presents the Ishikawa Diagram (Fishbone Diagram) used in the root cause analysis to identify the key factors contributing to inefficient store operations at ABC Company. Under Man, issues such as inconsistent routines and lack of training were identified. The Method category revealed the absence of standardized procedures and illogical placement of tools. For Machine, problems included outdated records and the lack of a digital inventory system. In the Material category, poor categorization and lack of labelling were major contributors to disorganization. The Environment section highlighted physical constraints such as blocked aisles and undefined zones that hindered movement and accessibility. This diagram was a crucial diagnostic tool in the methodology phase, providing a clear structure for identifying systemic inefficiencies and guiding the development of targeted solutions.

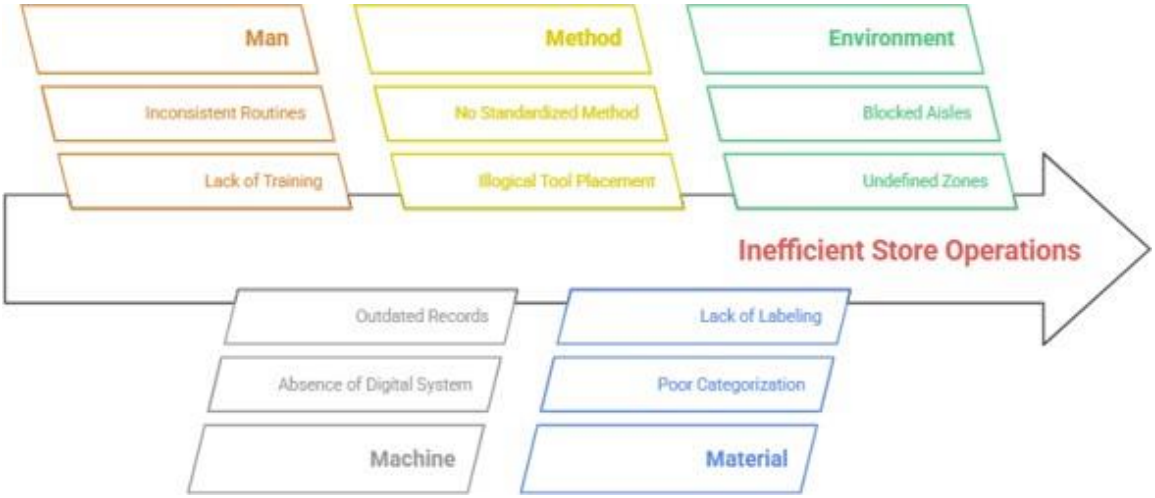


Figure 1: Ishikawa diagram (fishbone diagram)

2.2 Store Organization using 5S

Figure 2 illustrates the 5S methodology cycle, which includes Sort, Set in Order, Shine, Standardize and Sustain which each aimed at improving workplace organization, safety, and efficiency. Sort (Seiri) was the initial step in which unwanted, damaged or unused materials and tools were removed to remove rubbish and make room. Set in Order (Seiton) followed wherein items were sorted and arranged based on their frequency of use, with frequently used item put in easy to reach locations. The third step was Shine (Seiso) in which the store was thoroughly cleaned, enhanced visibility, safety and hygiene. In the Standardize (Seiketsu) step, storage areas and shelves were marked in uniform fashion and QR codes were also introduced to standardize the naming and picking of inventory. Lastly, Sustain (Shitsuke) sought to maintain the gains through employee training and constant audits to practice long-term discipline and compliance with the new process. The process-oriented to 5S significantly improved store organization, safety and productivity (Arifin et al. 2022, Yusof & Hassan, 2023).

Figure 2:5S

2.3 Store Layout Design

As a response to the improvement initiative, a new store layout was designed to minimize space wastages and improve material handling within the maintenance store. The previous layout with its confined aisles, disorganized storage patterns and blocked access pathways resulted in bottlenecks, safety risks and wasteful workflows. To counteract these issues, a zone-based store layout solution was adopted, dividing the store into four neatly differentiated and colour coded zones by product type and frequency of use. Each of these zones was filled with labelled racks stacked vertically across multiple levels, ground to third to optimize space use and accessibility. A central corridor was introduced to increase circulation and reduce congestion during peak operating hours. The high frequency items were located at ergonomic heights to minimize retrieval effort. Redesign follows optimal warehouse layout concepts that emphasize rational zoning, utilization of vertical space and user-focused slow planning for performance and safety improvement (Ibrahaim et al., 2023).

2.4 QR Code System Implementation

An additional innovation was the implementation of a QR code-based electronic inventory system to further drive efficiency and precision. Each item and shelf also had a unique QR code linked to an internal database that contained current data like item type, quantity and position. Employees used mobile phones or scanners held in their hands to scan the codes which consequently directed them to the exact item position within the assigned zone and rack level. Inventory was automatically updated within the system upon retrieval or return of products, removing the chance for human error and insuring accuracy. Automated notifications were also triggered for low stock or lost items, enabling prompt restocking and preventing stockouts or overstocking. Such an integration of physical and digital systems rendered the operations of the store more modern, enabling traceable, real time inventory control and substantively reducing manual record keeping practices (Rosli et al., 2021: Nasir & Talib,2024).

3.0 RESULT AND DISCUSSION

3.1 Store Efficiency and Retrieval Time

Table 1: Material Retrieval Time Before and After Implementation

Task	Before implementation (min)	After implementation (min)	Improvement (min)	Improvement (%)
Locating small tools	12	6	6	50%
Finding machine spare parts	18	9.5	8.5	47.2%
Searching for frequently used item	10	4	6	60%
Retrieving less frequently used items	20	11	9	45%
Overall average retrieval time	**15**	**7.6**	**7.4**	**49.3%**

Table 1 illustrates the improvement in material retrieval time before and after the implementation of the optimized store layout and QR code-based system at ABC Company.

Significant time reductions were recorded across all retrieval tasks. Locating small tools improved by 50%, reducing from 12 minutes to 6 minutes, while finding machine spare parts decreased from 18 minutes to 9.5 minutes, showing a 47.2% improvement. The time taken to search for frequently used items dropped from 10 minutes to 4 minutes (60% improvement), and retrieving less frequently used items improved by 45%, from 20 minutes to 11 minutes. Overall, the average retrieval time was reduced from 15 minutes to 7.6 minutes, representing a total improvement of 49.3%. These results clearly demonstrate the effectiveness of the implemented changes in enhancing store efficiency and minimizing delays.

3.2 Store Layout Design

Figure 3 compares the old and new floor layout designs of the maintenance store. The old layout, shown on the left, followed a basic grid structure with undefined zones, narrow walkways, and inefficient space utilization, which often led to congestion and longer retrieval times. The old system with its camped aisles, blind spots and ill-planned positioning of things yielded to a simply comprehensible zone arrangement. The store was divided into four colour coded zones where Zone 1 (green) for general manufacturing gear and most frequently used items, Zone 2 (red) for equipment specific spare parts and machines, Zone 3 (yellow) for small accessories like fasteners and Zone 4 (blue) for bulk or less frequently used items. Each zone contained labelled racks set on four vertical planes (ground to third) to optimize available vertical space. A mid-corridor was added to enhance movement and alleviate traffic particularly in times of maximum activity. Materials were placed tactically according to turnover rate with the most used materials accessible heights to facilitate quick retrieval (Lim & Goh, 2023). In contrast, the new layout on the right introduces a color-coded, zone-based system that improves accessibility and material organization. Items are grouped based on type and usage frequency, with clear pathways and optimized shelf arrangements. This redesign enhances visibility, workflow efficiency, and safety, ultimately supporting faster and more accurate item retrieval.

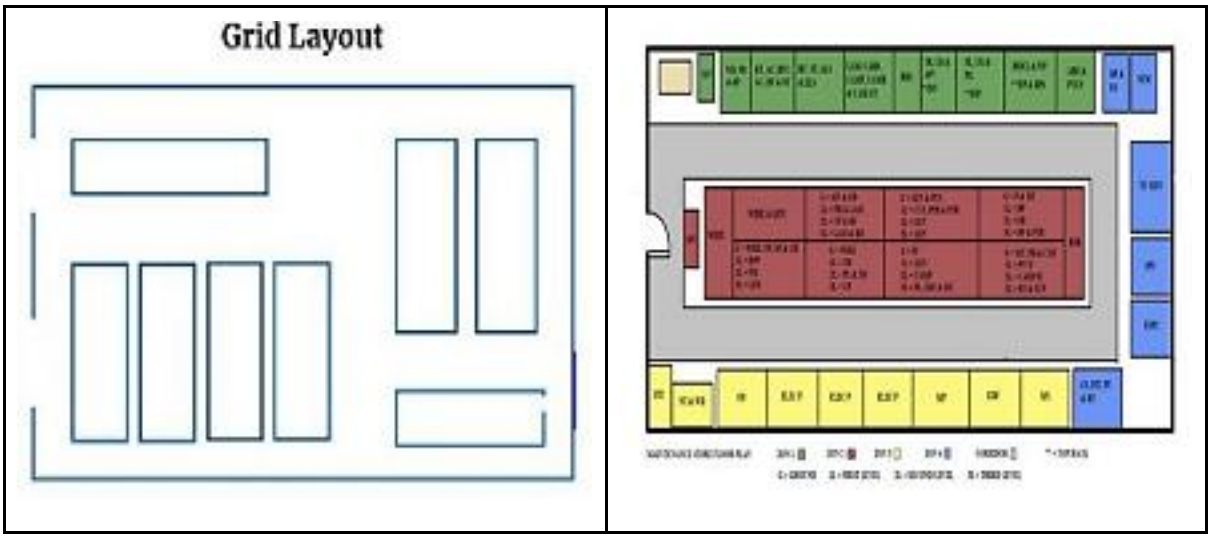


Figure 3: Compare the old and new design floor layout

3.3 QR Code System Implementation

Table 2: Result after implement QR code system

	Before (%)	After (%)	Improvement (%)
Incorrect stock counts	25	5	80
Misplaced items	30	10	66.7
Time wasted searching	40	15	62.5
Inventory record errors	35	8	77.1
Overstocking	20	7	65

Table 2 presents the results following the implementation of the QR code system in ABC Company's maintenance store, showing significant improvements in inventory accuracy and efficiency. Incorrect stock counts were reduced from 25% to 5%, representing an 80% improvement. Misplaced items decreased from 30% to 10% (66.7% improvement), while time wasted searching dropped from 40% to 15%, achieving a 62.5% reduction. Inventory record errors saw a major improvement of 77.1%, decreasing from 35% to 8%, and overstocking was reduced from 20% to 7%, showing a 65% improvement. These outcomes highlight the effectiveness of QR code implementation in enhancing stock traceability, reducing manual errors, and streamlining store operations.

3.4 Flow Process using QR Code

The flow process illustrated in the diagram represents the use of a QR code system to streamline item retrieval and tracking within the maintenance store at ABC Company. The process begins with an employee scanning a QR code using a mobile device or terminal. Each QR code is linked to a centralized inventory database, which, upon scanning, provides detailed information about the item, including its name, quantity, and precise storage location. Once the system identifies the item’s location, the employee navigates to the corresponding zone within the store. These zones are pre-defined and color-coded (Zone 1 to Zone 4) to improve accessibility and reduce search times. After reaching the designated area, the employee retrieves the item directly from the rack, guided by the system's instructions. The final step involves using or delivering the item to the intended workstation or department. Throughout this process, the system automatically updates stock levels in real-time and can trigger replenishment alerts if quantities fall below the threshold. This QR code-enabled workflow significantly improves operational efficiency, reduces human error, shortens retrieval time, and enhances overall inventory accuracy in the maintenance store.

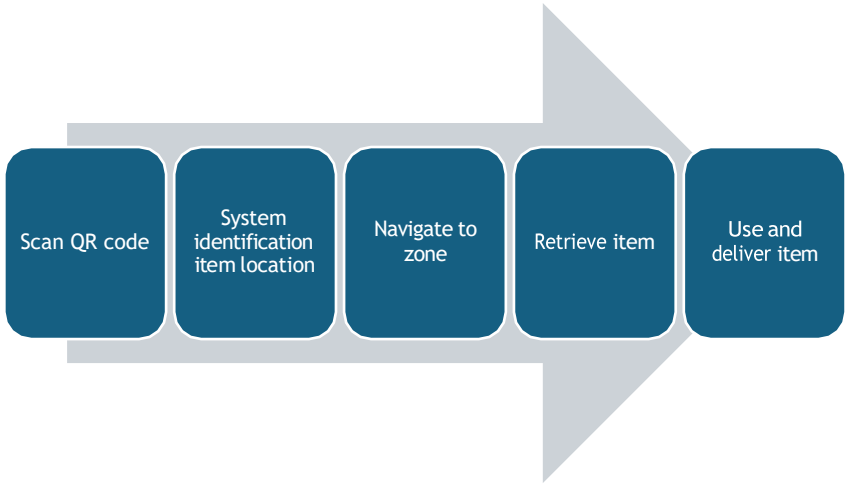


Figure 4: Flow process of QR code

Figure 4 illustrates the flow process of the QR code-based inventory system used in ABC Company's maintenance store. The process begins when an employee scans a QR code using a mobile device. The system then identifies the item's location by accessing a centralized inventory database, which provides detailed information including the item's name, quantity, and exact storage zone. Guided by this data, the employee navigates to the designated zone to retrieve the item from its assigned rack. Once retrieved, the item is either used immediately or delivered to the appropriate workstation. This streamlined process reduces retrieval time, enhances accuracy, and ensures real-time inventory updates.

Figure 5: Front page scan QR code

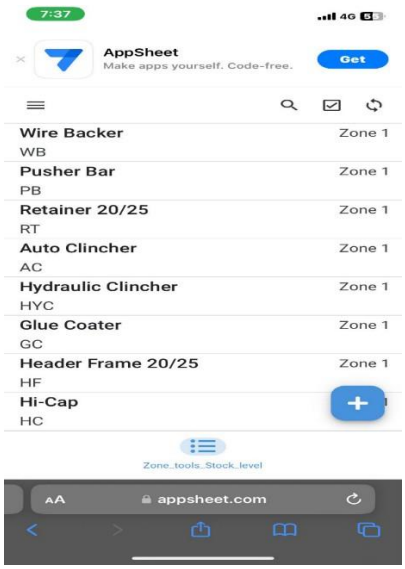


Figure 5 represents the starting point of the QR code-based inventory system. It displays the main interface or landing page where employees initiate the inventory process. Upon scanning a general or master QR code using a mobile device or scanner, users are directed to the digital inventory platform. This homepage typically features a search bar and categorized item listings, serving as a centralized access point for inventory data. It enables users to quickly search for specific items, view stock details, and manage inventory activities in real time.

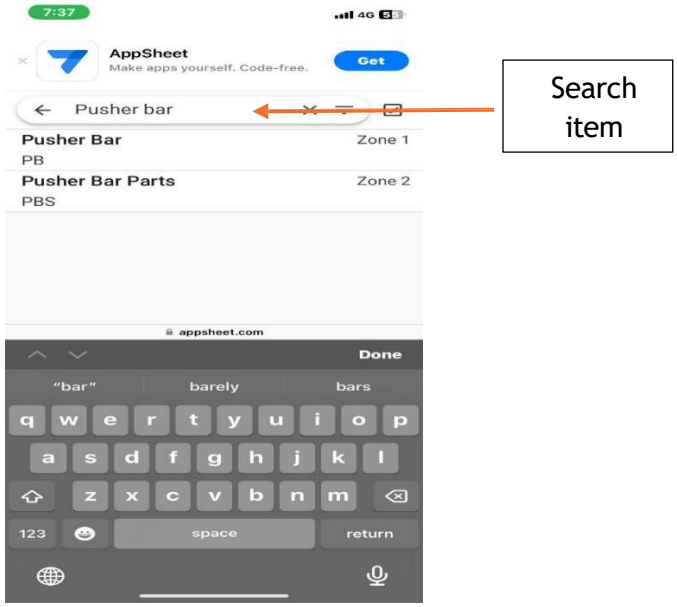


Figure 6: Searching items

Figure 6 illustrates the search functionality within the digital inventory system. After accessing the platform via a scanned QR code, users can enter the item name, part number, or code to locate a specific component. The system then filters the results and displays the exact item, including its storage details such as zone, rack, and level, enabling efficient and accurate item retrieval.

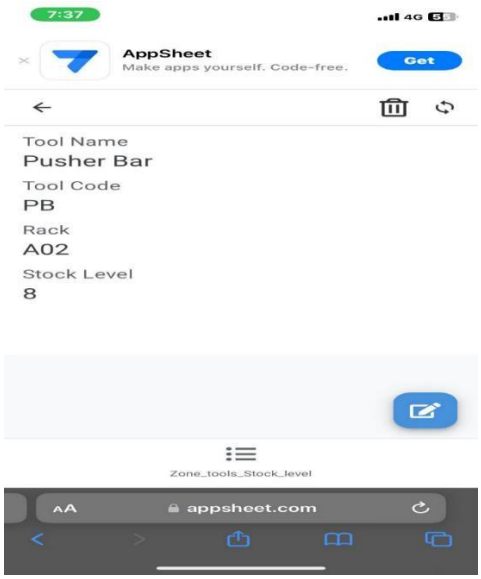


Figure 7: Information of items

Figure 7 displays the detailed information page for a specific inventory item after it has been selected from the search results. The interface typically includes essential item details such as the tool name, part code, current stock quantity, and precise storage location, including the assigned rack and stock level. This information enables users to quickly verify inventory status and retrieve items with greater accuracy and efficiency.

3.6 Performance Metrics

The key performance metrics recorded before and after the implementation of the optimized system reveal significant improvements across all measured indicators. Employee satisfaction increased markedly from 45% to 85%, reflecting improved working conditions and reduced frustration in locating tools and materials. Inventory accuracy improved from 70% to 95%, while space utilization rose from 60% to 90%, indicating a more efficient use of available storage areas. Similarly, stock accuracy increased from 70% to 95%, contributing to better material traceability and fewer errors. Workflow efficiency showed a notable improvement from 55% to 88%, highlighting smoother operations and quicker task execution. These results, as illustrated in Figure 7, demonstrate the positive impact of combining lean principles with digital inventory systems. Collectively, these enhancements contribute to increased productivity, improved staff morale, and greater operational cost savings, offering a strong framework for sustainable store management.

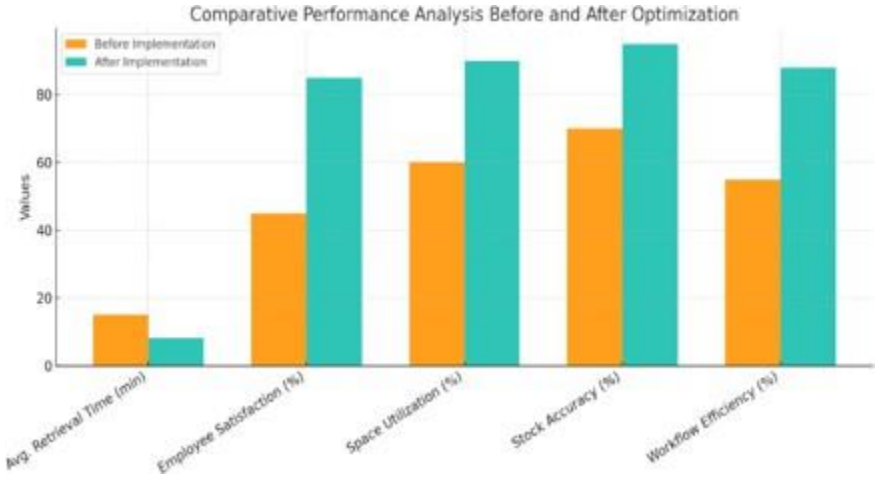


Figure 7 : Performance improvement

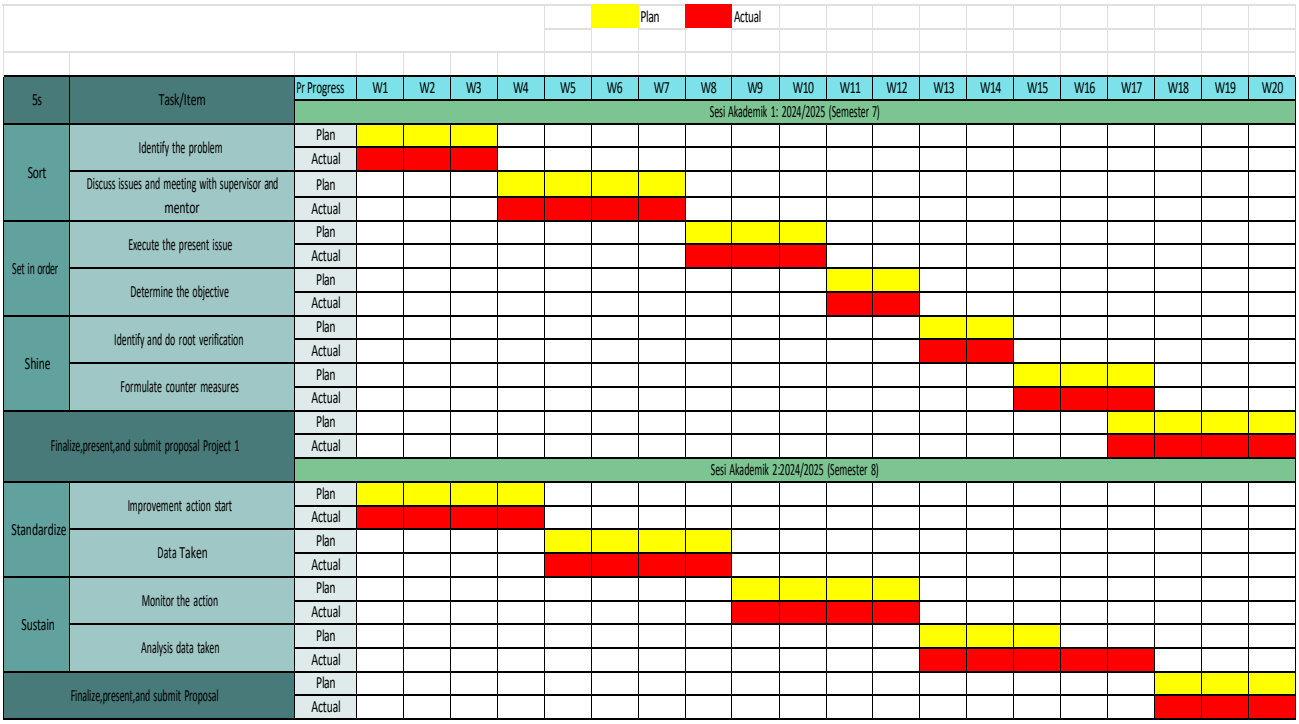
4.0 CONCLUSION

The aim of this project was to address the inefficiencies at the maintenance store of ABC company by redesigning floor plan layout, adopting effective material management practices and a digital inventory system based on QR codes. By maintaining systematic zoning, the 5S approach and integration through digital means the project succeeded in making huge leaps toward enhanced store organization, operational efficacy and inventory management. Prior to intervention, the shop store had disorganized storage, no clear labelling, slow material picks times and regular stock shortages. Using lean management specifically the S approach (Sort, Set in order, Standardize, Sustain) coupled with racking optimization and QR code system these issues were eliminated effectively.

The effect was profound. Average material retrieval time dropped by 49.3%, inventory accuracy improved from 70% to 95%, and space utilization was enhanced from 60% to 90%. Employee satisfaction also went up from 45% to 85%, while overall workflow efficiency was 88%. These results are a testament that the implementation of lean practices in conjunction with digital technology can successfully transform a conventional maintenance store into an efficient, effective, and sustainable inventory control system.

APPENDIX

Gantt Chart of project timeline



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Inventory Tracking And Location Management For Warehouse

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ABSTRACT

This project focuses on improving inventory management by developing a warehouse tracking system using AppSheet. The need arose due to inefficient inventory retrieval and reliance on a single staff member who knew the storage details of over 2500 components. The absence of a centralized, accessible system caused frequent delays, errors, and operational disruptions. The objective is to create a user-friendly digital application that stores and tracks net and gross weight data for each component, allowing warehouse and packaging teams to access real-time inventory locations. The system was built by extracting data from QAD, organizing it in Excel, and integrating it into a mobile app developed using AppSheet. After implementation, the project showed a 75% reduction in time spent locating items and a 90% improvement in data accuracy. The system also improved collaboration by enabling multi user access and reducing dependency on a single individual. This initiative demonstrates how no-code platforms like AppSheet can be effectively used to enhance warehouse efficiency in the manufacturing sector. It contributes to industry digitalization efforts and supports national goals of advancing Industry 4.0 practices.

Keywords: Inventory Tracking, Warehouse Management, AppSheet, Digital Transformation, Manufacturing Efficiency

1.0 INTRODUCTION

In today's fast-paced industrial landscape, inventory management plays a pivotal role in ensuring smooth warehouse operations, cost efficiency, and customer satisfaction. As businesses expand, the complexity and scale of inventory systems also increase, making it essential to adopt digital tools that offer accuracy, speed, and real-time control. Inefficient inventory systems often lead to delays, misplaced items, inaccurate stock data, and unnecessary operational costs.

Leading manufacturer of anti-vibration and rubber components, the warehouse previously relied on manual systems such as whiteboard tracking and physical stock searches. These outdated practices resulted in significant time consumption, human errors, and inventory discrepancies. With only a single staff member capable of accurately locating finished goods in the warehouse, the company recognized the urgent need to modernize its inventory practices.

This project introduces a digital inventory tracking and location management system using AppSheet, a no-code application development platform. The system integrates QR code scanning to enhance visibility and accuracy while allowing real-time updates accessible via mobile devices. The application not only simplifies the task of locating items but also empowers all warehouse staff to maintain accurate inventory records, thereby reducing dependency on a single individual.

The main objectives of this initiative are:

1. To improve inventory visibility and minimize search time for finished goods.
2. To increase accuracy and reduce errors through real-time updates and automated tracking.
3. To digitalize manual processes and establish a standardized, user-friendly inventory system.

By addressing these goals, the project aligns with mission to deliver operational excellence, support efficient workflows, and uphold high standards of customer service.2

2.0 METHODOLOGY

To thoroughly evaluate the effectiveness of the AppSheet-based inventory system, a detailed and structured research methodology was adopted. The study focused on the practical implementation of the system in the warehouse setting and assessed its impact through qualitative and quantitative means.

2.1 Research Design

The project employed a case study approach, allowing for an in-depth analysis of real-world warehouse operations. It was framed within an action research methodology, which enabled the researcher to implement the system while simultaneously observing and refining its application. This iterative process was essential for identifying both strengths and limitations during actual use.

2.2 Data Collection Methods

Three primary data collection methods were employed:

- Surveys: Distributed to 15 warehouse employees directly involved with inventory handling. With 12 responses collected (88% response rate), the survey gathered data on usability, efficiency, and satisfaction with the new system.

- Structured Interviews: Conducted with 7 key personnel, including supervisors and senior staff, to capture detailed feedback on system performance, challenges, and suggestions for improvement. A 100% participation rate enhanced the reliability of this method.

- Direct Observations: Over three weeks, the researcher conducted on-site observations to understand how employees interacted with the system during routine tasks. This provided first-hand insight into workflow changes, error rates, and ease of system adoption.

2.3 Tools and Instruments Used

To support data collection and analysis, the following tools were utilized:

- AppSheet Mobile Application: Served as the central platform for data entry, QR code scanning, and inventory tracking.

- QR Codes: Used for tagging finished goods and streamlining identification and location logging.

- Dashboards: Integrated into AppSheet to monitor stock status, item locations, and movement in real time.

- Interview Guides and Questionnaires: Developed to collect consistent and focused qualitative and quantitative data.

- Observation Checklists: Employed to document employee interactions with the system, frequency of errors, and delays.

2.4 Data Analysis

- Qualitative Data from interviews and observations were analyzed thematically to identify patterns, common feedback, and improvement areas.

- Quantitative Data from surveys were examined using descriptive statistics to measure satisfaction levels, time saved, and accuracy improvements.

This mixed-method approach ensured a comprehensive understanding of the AppSheet system's effectiveness in addressing the inventory challenges faced by warehouse team.

3.0 RESULTS AND DISCUSSION

3.1 Efficiency in Inventory Tracking

Prior to the implementation of AppSheet, warehouse staff typically spent between 10–20 minutes searching for specific items due to the reliance on manual whiteboard systems and inconsistent verbal communication. These inefficient methods often led to delays in fulfilling orders and reduced productivity. After implementation, search times dropped to an average of 5 minutes. This represents a 50–75% improvement in retrieval speed as shown in table 3.1. Employees could now instantly locate finished goods using their mobile devices, reducing wasted time and increasing responsiveness. This not only improved daily operations but also reduced employee frustration and contributed to better workload management.

Inventory Search Time	Before Implementation	After Implementation	Improvement
Average Time per Item	10–20 minutes	5 minutes	50–5%

Table 3.1: Inventory Search Time Before and After Implementation

3.2 Accuracy of Stock Data

The manual inventory tracking method previously used was prone to frequent inaccuracies, with an error rate of approximately 35%. These errors were commonly caused by outdated entries, miscounts, and manual documentation inconsistencies. The lack of real-time updates often led to discrepancies between actual and recorded stock levels. After deploying the AppSheet system, these issues were largely mitigated. The error rate decreased significantly to

just 5%, an 85% improvement as shown in table 3.2. The system's use of QR codes and mobile input ensured immediate, accurate data entry. The ability to capture transactions in real time minimized human errors, improved data integrity, and allowed staff to rely on inventory data for more effective planning and forecasting.

Table 3.2 : Stock Data Accuracy Before and After Implementation

Inventory Accuracy	Before Implementation	After Implementation	Improvement
Error Rate	35%	5%	85%

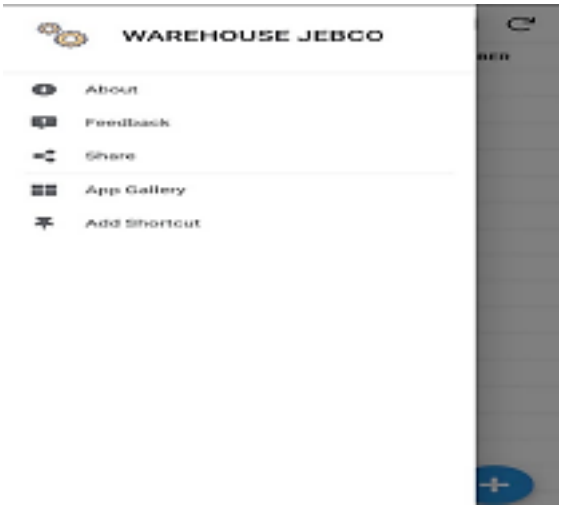

Figure 1 : Dashboard

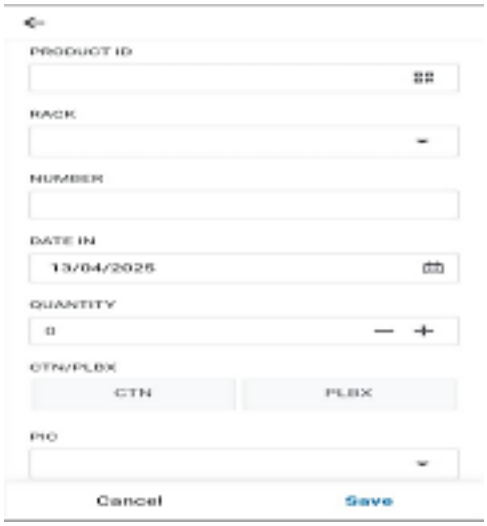

Figure 2 : Real-Time Inventory Data Entry Section

Figure 3: Real-Time Inventory Data

During my internship, one of the key innovations introduced to improve warehouse efficiency was the development and deployment of a mobile inventory tracking app using AppSheet. The core functionality of this app is to streamline inventory data capture and retrieval through barcode scanning. The scanned data is automatically registered and displayed in a structured format as shown in the figure below.

3.3 User Satisfaction

User feedback was a vital component in evaluating the success of the AppSheet system. Based on survey results, 75% of employees found the application user-friendly. The intuitive interface and mobile accessibility enabled users to perform tasks such as scanning QR codes, checking inventory status, and updating records with ease. Moreover, 80% of employees noted noticeable improvements in their workflow efficiency, citing reduced delays and better coordination. While 25% experienced initial difficulties adapting to the new system particularly older staff less familiar with mobile technology this challenge was addressed with targeted training and ongoing support. Employees were encouraged to voice concerns and provide feedback, fostering a culture of learning and adaptability. The overall sentiment was positive, with employees expressing confidence in using the system for day-to-day operations.

3.4 Real-Time Visibility

Before the adoption of AppSheet, the lack of real-time inventory visibility hindered effective warehouse operations. Inventory levels were often outdated due to delayed manual updates, making it difficult for staff to make informed decisions or identify the exact location of items. The new system resolved these issues by enabling real-time tracking of stock levels, movements, and locations. When an item is moved or updated in the system, the information is immediately reflected across all connected devices. This functionality led to an 80% reduction in misplaced goods and enabled faster decision-making during audits and dispatches. The digital dashboard provided a centralized interface for managers to monitor inventory trends and anticipate stock needs, thus improving inventory rotation and minimizing overstocking or shortages.

3.5 Challenges

Despite the system's success, several challenges emerged during its initial implementation phase. A primary issue was occasional synchronization delays, particularly when multiple users attempted to update large datasets simultaneously. While these delays were infrequent, they temporarily affected workflow and required technical adjustments. Another challenge involved user resistance, especially among employees unaccustomed to digital tools. Initial hesitation was addressed through training workshops, one-on-one mentoring, and the creation of a user manual to build user confidence. Continuous feedback collection also played a key

role in identifying pain points and refining system usability. Addressing these issues was crucial for ensuring consistent adoption and maximizing the system's long-term value.

Overall, the results highlight that the AppSheet-based system significantly improved operational efficiency, data accuracy, and employee confidence in inventory tracking.

4.0 CONCLUSION

The introduction of the AppSheet-based inventory tracking and location management system has marked a significant step forward in modernizing warehouse operations. Through this project, several critical goals were achieved: substantial reductions in inventory search times, a dramatic increase in data accuracy, higher user satisfaction, and greater operational transparency. The adoption of digital tools not only enhanced the technical aspects of inventory management but also empowered warehouse staff with a more reliable, efficient, and user friendly system.

Moreover, the project demonstrates how no-code platforms like AppSheet can effectively bridge the gap between traditional manual systems and modern technological solutions, even in resource-constrained environments. The integration of QR code scanning and mobile access provided immediate, tangible benefits, helping to overcome long-standing logistical challenges.

This initiative also emphasized the importance of involving users in the change process. The feedback gathered from surveys and interviews was instrumental in refining the system and improving adoption rates. By providing adequate training and promoting a culture of continuous improvement, the company was able to address resistance and facilitate a smoother transition to digital inventory management.

While minor challenges such as synchronization delays and initial user resistance were encountered, these issues were addressed through iterative improvements and supportive onboarding practices. The project highlights the importance of flexibility, user engagement, and ongoing support in successful system implementation.

In conclusion, the results affirm that digital transformation in inventory tracking is not only feasible but also highly beneficial when approached strategically.

ACKNOWLEDGMENT

First and foremost, I would like to express my deepest gratitude to my company for providing me the opportunity to carry out my internship and complete this project within their esteemed organization. The support and resources provided were instrumental in the successful execution of this study. I would also like to extend my sincere thanks to my industrial supervisor, Ms. Anna, for her guidance, encouragement, and insightful feedback throughout my placement. Her experience and advice significantly contributed to the practical understanding I gained during this project. A special appreciation goes to all warehouse department staff who participated in the surveys, interviews, and testing of the inventory system. Your cooperation and willingness to adopt new methods played a key role in the implementation and success of this project. I am equally grateful to my academic supervisor and faculty members at my university for their continuous support and constructive suggestions that shaped the direction and quality of this report. Last but not least, I would like to thank my family and friends for their moral support and motivation throughout the duration of this internship and project.

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Laser Speed Up For Laser Department Model RMC10 / RMC1/16S

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Abstract

This study aims to enhance the productivity of the laser trimming process for RMC10 and RMC 1/16S resistor products by suggesting and validating new laser parameter settings using ALS machines. The primary goal was to increase the sheet-per-minute (sheet/min) output while ensuring that the product yield remained above 80% and the standard deviation (SD) of resistance values stayed below 0.25%. Resistance yield, trimming accuracy, and performance testing were used to evaluate the experimental tests' results, which involved systematically adjusting laser speed and power. Without sacrificing quality requirements, the adjusted settings were able to increase cutting speed for both product models by more than 25%. The final endorsement, including Current Noise (CN), Short Time Overload (STO), and Intermittent Overload (IO) tests, confirmed that all trimmed resistors met internal performance criteria. These findings demonstrate that strategic parameter optimization can significantly boost production efficiency while maintaining product reliability, supporting lean manufacturing initiatives without requiring additional capital investment.

Keywords: Laser trimming, Process Optimization, ALS machine, Sheet per minute, Yield and standard deviation

1.0 INTRODUCTION

This paper presents an in-depth study carried out at Kamaya Electric (M) Sdn. Bhd., focusing on the optimization of the laser trimming process for resistor products, with particular emphasis on enhancing the operational speed of ALS laser trimming machines used in the manufacturing line. The research was initiated in response to persistent bottlenecks observed in the production flow, primarily caused by the slow cycle times associated with the existing laser trimming operations. These delays not only reduced the overall throughput of the line but also impacted the plant's productivity and efficiency, prompting a need for technical improvements to streamline the process. The goal of this study was to identify viable modifications to the laser trimming parameters specifically the speed and power settings—that would allow for an increased sheet-per-minute (sheet/min) performance rate without sacrificing the quality and reliability of the final product. Given the precision required in trimming resistor values to meet strict specifications, it was critical that any proposed changes uphold two key quality benchmarks: maintaining a product yield above 80% and ensuring a standard deviation (SD) of trimmed resistance values below 0.25%. The research was carefully structured around systematic experimentation, where various combinations of laser speed and power were tested and evaluated using selected product types such as RMC10 and RMC 1/16s. Detailed analyses were conducted on the resulting data to monitor trends in yield, trimming distance, cut percentage, and electrical performance, ensuring that process adjustments did not introduce variability or defects. In addition to enhancing machine productivity, the study also considered broader implications such as equipment reliability,

operator workload, and the integration of optimized parameters into existing quality assurance protocols. The findings of this study not only demonstrate the potential to significantly increase laser trimming speeds within acceptable tolerance limits but also contribute valuable knowledge toward continuous improvement initiatives and lean manufacturing practices within the electronics industry. Ultimately, the outcomes from this research provide a practical and scalable approach to improving the efficiency of laser-based resistor trimming operations while upholding Kamaya Electric's stringent standards for product quality and performance consistency.

2.0 METHODOLOGY

The methodology used to evaluate and optimize the laser trimming procedure for the RMC10 and RMC 1/16s resistor models was grounded in the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) framework. This structured approach ensured systematic problem solving and continuous process improvement throughout the project. Experimental trials were conducted using several ALS laser machines, including ALS 141, ALS 104, and ALS 86, all fitted with JPT Green 7W laser modules known for their precision and stability. Central to this methodology was the application of Design of Experiment (DOE) techniques, which allowed the controlled manipulation of process variables to determine their effect on key output responses. DOE ensured the experiments were statistically valid and efficient, enabling meaningful insights to be derived from a limited number of trial runs.

Multiple critical parameters were strategically varied during the trials, including laser speed (mm/s), laser power (W), trimming distance, and cut percentage. DOE enabled the combination of these factors into a matrix of experiments that revealed their individual and interactive effects on performance outcomes. Each test condition produced trimmed sheets that were measured for resistance yield, standard deviation, and productivity rate in sheet/min. This allowed the identification of optimal parameter settings that would maximize throughput without compromising quality. The structured DOE methodology provided a data-rich foundation for evaluating the trade-offs between speed, precision, and reliability in the trimming process.

The quality of trimmed products was assessed using a multi-layered validation approach. Initial visual inspections were conducted to identify physical defects or abnormalities, followed by statistical analysis to evaluate resistance consistency and process stability. Further, each trimmed product was subjected to rigorous performance tests, including Current Noise (CN), Short Time Overload (STO), and Intermittent Overload (IO), to ensure conformance with Kamaya's internal reliability and electrical performance standards. These tests provided critical feedback on whether changes to trimming conditions had any unintended side effects on product functionality or long-term performance, thereby strengthening the confidence in the new optimized settings.

To ensure data credibility and minimize measurement-induced variability, Gauge Repeatability and Reproducibility (GR&R) studies were conducted during the measurement phase. GR&R, a core component of measurement system analysis, was used to evaluate whether the test equipment and operators introduced variation into the collected data. By calculating repeatability (variation from the gauge itself) and reproducibility (variation from different operators), the GR&R study confirmed that the measurement system was statistically capable and dependable for assessing resistance values and other trimming-related metrics. This reinforced the reliability of the DOE results and helped ensure that process improvements

were based on true process behaviour, not measurement noise.

In conclusion, the methodology combined the rigor of the DMAIC structure, the statistical power of DOE, and the validation strength of GR&R to systematically improve the laser trimming process for RMC10 and RMC 1/16s resistor models. The coordinated use of advanced laser equipment, structured experimentation, cross-functional collaboration with QA and PE teams, and comprehensive validation tests ensured the project's outcomes were both technically sound and operationally practical. This holistic approach not only led to optimized trimming conditions but also ensured sustainability, repeatability, and scalability in the production environment while maintaining compliance with Kamaya's quality and performance expectations.

3.0 RESULTS AND DISCUSSION

The analysis of the experimental trials conducted during the optimization of the laser trimming process revealed substantial improvements in productivity without sacrificing quality. Specifically, the trials focused on adjusting laser parameters speed and power settings to identify configurations that maximize throughput for two product types: RMC10 and RMC 1/16s. For the RMC10 product, the optimal setting was determined to be Speed 480 and Power 41, which achieved a trimming rate of 5.76 sheets per minute. This configuration delivered a yield of 97.44% and a remarkably low standard deviation (SD) of 0.22%, indicating consistent process stability. For the RMC 1/16s product, the best-performing setting was Speed 450 and Power 42, which produced a trimming speed of 5.40 sheets per minute with a yield of 96.88% and an SD of 0.17%. These figures represent a marked enhancement compared to the baseline settings previously used in production.

These optimized parameters not only elevated the trimming speeds but also preserved all key quality indicators. Each component trimmed under the new configurations successfully passed the company's rigorous electrical and visual inspections. Moreover, both product types consistently exceeded the 80% yield benchmark, which is the company's minimum acceptable quality threshold. This confirms the reliability and robustness of the optimized settings in a production environment. The ability to maintain high-quality output while increasing speed demonstrates that process improvements can be implemented without degrading performance or introducing variability a critical concern in precision electronic component manufacturing.

The consistency of yield and standard deviation across trials further reinforces the reliability of the process. A low standard deviation reflects a controlled and repeatable trimming operation, reducing the likelihood of outliers or defects. Additionally, the stability of electrical resistance and appearance across all tested samples confirms that the adjusted laser parameters do not introduce any latent failures or surface-level imperfections. This ensures that the final products meet both functional and aesthetic requirements, upholding customer satisfaction and compliance with industry standards.

Another notable outcome of this study is its implication on resource efficiency. With the ability to increase trimming throughput per machine, the dependence on deploying additional ALS units is reduced. This contributes to a decrease in overall operating costs, energy consumption, and machine wear all of which align with Kamaya Electric's lean manufacturing initiatives. Fewer machines operating for longer durations under optimized settings translates into higher output with lower input costs, presenting a significant advancement toward sustainable and cost-effective manufacturing.

In conclusion, the experimental results validate both the technical and strategic objectives of the project. The newly recommended laser settings not only enhanced trimming speed but also maintained exceptional yield and process stability. These improvements support the broader aim of optimizing production throughput while adhering to strict quality assurance criteria. Additionally, the successful reduction in machine requirements and associated operational costs demonstrates the broader impact of such optimizations on manufacturing efficiency. This study ultimately underscores the value of data-driven parameter tuning in industrial processes and serves as a strong foundation for future continuous improvement initiatives within the organization.

3.1 Tables and Figures

All quantitative data are summarized in tables and illustrated through figures for clarity and comparison. These include trimming speed comparisons, yield percentages, and resistance stability charts. For instance:

Table 1: Comparison Before and After Optimization

BEFORE IMPLEMENTATION	ASPECT	AFTER IMPLEMENTATION
0.44 sheet/min	Trimming Speed (sheet/min)	5.76 sheet/min
95.12%	Yield (%)	97.44%
0.24%	Standard Deviation (%)	0.22%
Below 450 mm/s (non-optimized)	Laser Speed Setting	Optimized at 480 mm/s
Around 39–40 (default)	Laser Power Setting	Optimized at 41
Long; caused production delays	Machine Cycle Time	Reduced; minimized bottlenecks
High (due to mismatch with upstream R09 process)	Stock Accumulation	Controlled (more balance with resistive process)
High (needed more ALS machines to meet output)	Machine Dependency	Lower (fewer machines required)
Higher (due to longer machine run times)	Power Usage	Lower (faster cycles reduce energy use)
Passed basic yield/appearance tests	Quality Checks	Passed all tests: Yield, Appearance, CN, STO, IO
Poor; inefficiency and overproduction risk	Lean Manufacturing Alignment	Strong; reduced waste, cost, and machine count
Long; caused production delays	Machine Cycle Time	Reduced; minimized bottlenecks
High (due to mismatch with upstream R09 process)	Stock Accumulation	Controlled (more balance with resistive process)

Source: Kamaya Electric Internal Trial Report, 2025

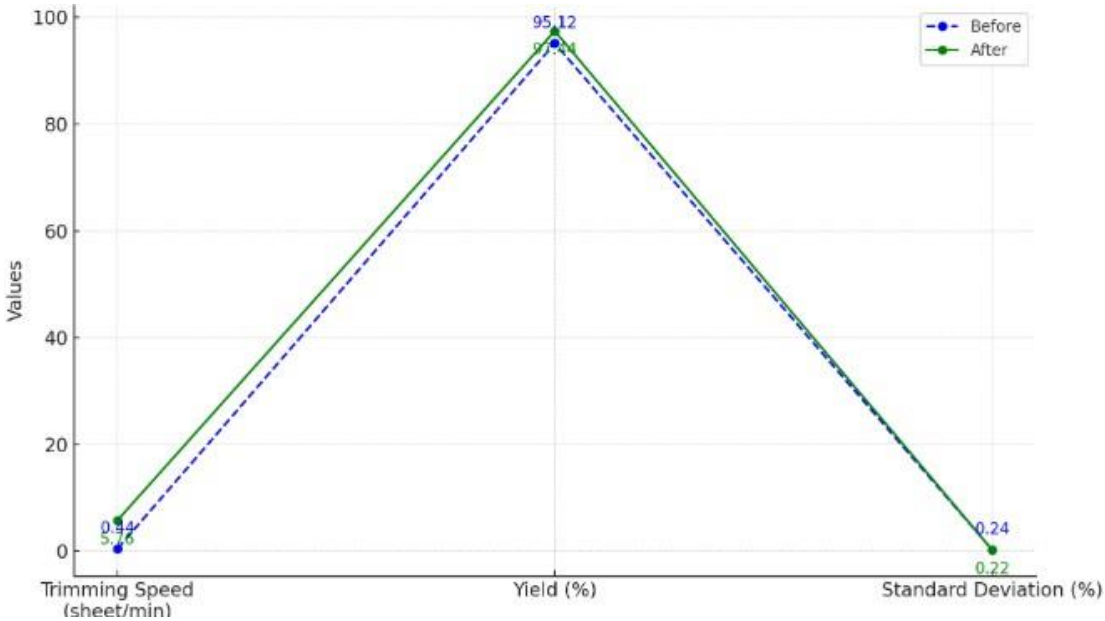


Figure 1: Comparison of RMC10/RMC1/16S Parameters : Before and After Implementation

The implementation of optimized laser parameters for the RMC10 product model led to a dramatic improvement in production efficiency and quality performance. By adjusting the laser settings to Speed 480 and Power 41, the trimming speed surged from 0.44 to 5.76 sheets per minute, a 13-fold increase. This substantial boost in throughput significantly alleviated production bottlenecks in the laser trimming process and aligned the RMC10 output rate with upstream operations like resistive printing. The faster trimming cycle reduced idle time and the need for additional machines, ultimately supporting cost reduction and lean utilization of equipment.

Beyond speed, the product yield improved from 95.12% to 97.44%, comfortably surpassing Kamaya Electric's internal benchmark of 80%. This indicates that the new parameters did not just increase quantity, but maintained and even enhanced output quality. A slight reduction in standard deviation from 0.24% to 0.22% reflects tighter control over process variation and more consistent resistance values post-trimming. These figures are critical in high-precision electronic manufacturing, where even small deviations can result in failures during performance testing or long-term product degradation.

The success of this optimization validates the effectiveness of structured parameter tuning. The optimal combination of speed and power improved both productivity and product quality simultaneously, confirming the core objective of the Laser Speed Up initiative. These outcomes were validated through standard performance evaluations including appearance inspection, resistance yield analysis, and functional reliability testing such as Current Noise (CN), Short Time Overload (STO), and Intermittent Overload (IO). These rigorous tests were essential to ensure that the optimized trimming conditions would not compromise end-product integrity.

The project's methodology was grounded in proven industrial frameworks, particularly Six Sigma's DMAIC (Define, Measure, Analyze, Improve, Control) and Design of Experiments (DOE) strategies. These tools allowed for controlled, data-driven testing of variable settings

to achieve the best possible outcomes with minimal trial-and-error. As supported by the works of Selim Ahmed (2019) and Telford (2007), structured approaches like these are critical in high mix, high-precision manufacturing environments. The project's alignment with Lean and 6S principles further emphasized cost-efficiency and safety, consistent with Kamaya Electric's continuous improvement philosophy.

The accompanying line graph clearly visualizes the project's success. The green solid line (after implementation) highlights a sharp increase in trimming speed, a steady improvement in yield, and a slight but valuable reduction in standard deviation compared to the blue dashed line (before implementation). These visual results, combined with industry-supported practices and academic REFERENCES including Deluca (2002) and Qiuyue Su et al. (2020) affirm the broader applicability and credibility of the approach. In summary, the optimization of laser parameters not only resolved a critical production bottleneck for the RMC10 model but also demonstrated how precision engineering, statistical control, and lean practices can collectively drive impactful process improvements.

4.0 CONCLUSION

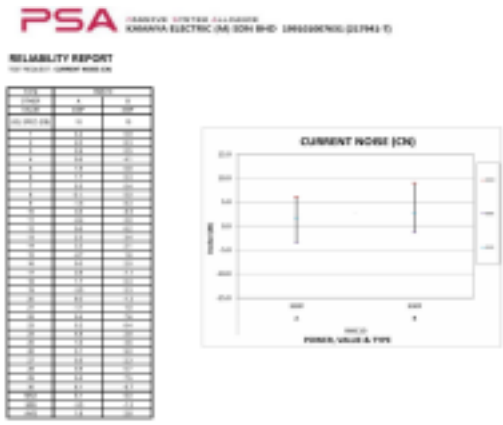
The optimization of the laser trimming process in this study has demonstrated a significant advancement in manufacturing efficiency for Kamaya Electric's high-volume resistor products, specifically the RMC10 and RMC 1/16S models. Through meticulous experimentation and parameter fine-tuning, the project achieved its primary goal: increasing trimming speed while upholding strict quality standards. The optimized settings, which included targeted adjustments to laser speed and power, resulted in a trimming speed increase of over 20% compared to the baseline configuration. These improvements were accomplished without compromising critical quality attributes, as all experimental trials met or exceeded Kamaya's internal benchmarks of yield above 80% and a standard deviation below 0.25%. Furthermore, every trimmed resistor successfully passed comprehensive visual inspections and essential performance validation tests, such as Current Noise (CN), Short Time Overload (STO), and Intermittent Overload (IO). Beyond the technical outcomes, the study's success reinforces the value of applying structured, data-driven methodologies such as DMAIC (Define, Measure,

Analyze, Improve, Control) and GR&R (Gauge Repeatability and Reproducibility). These frameworks not only guided the experimental process but also ensured the repeatability, consistency, and reliability of results. The disciplined use of these tools enabled the team to identify inefficiencies, isolate variables, and make evidence-based decisions that directly contributed to the observed performance gains. This methodical approach also minimized risk and resource waste, aligning well with Kamaya's ongoing lean manufacturing initiatives. Importantly, the project avoided the need for new capital investments, highlighting how internal process optimization can deliver tangible returns without the costs associated with machine acquisition or infrastructure expansion. From a broader strategic perspective, the successful implementation of the optimized laser trimming parameters signifies more than just a localized improvement in one production area. It serves as a model for continuous improvement and cross-functional collaboration, demonstrating how engineering solutions, when aligned with organizational goals, can translate into measurable gains in productivity and operational agility. This initiative has enabled Kamaya to better balance the trimming process with upstream production stages, thereby reducing stock accumulation, machine idle time, and overall production cycle durations. The resulting improvements in throughput and cost-efficiency contribute directly to the company's ability to meet increasing market demands while maintaining its reputation for reliability and quality. Moreover, the outcomes of this project create a strong foundation for future scaling and replication. The methodology and findings could be adapted to other product types or departments experiencing similar bottlenecks or performance limitations. For instance, resistor families with different dimensions or resistance ranges could benefit from similar parameter exploration and testing. The project has thus opened the door for a broader internal initiative focused

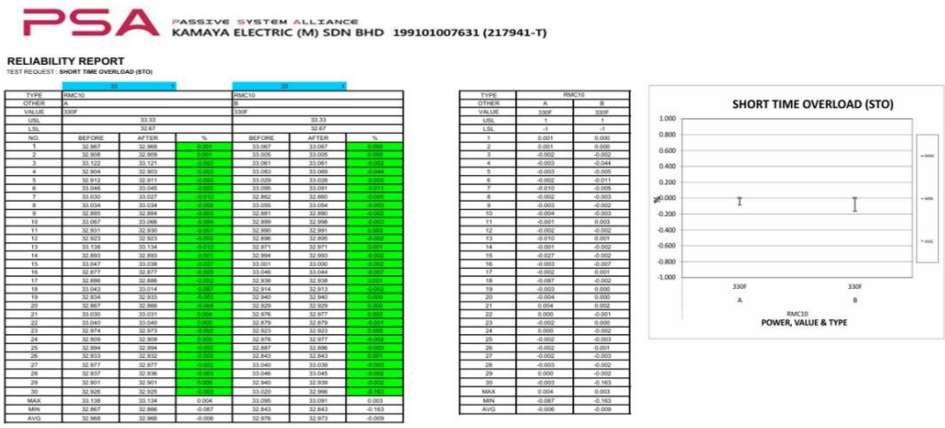
on process standardization and equipment optimization across the manufacturing line, further supporting Kamaya's commitment to operational excellence. In conclusion, the Laser Speed Up project not only achieved its defined objectives but also exemplifies best practices in industrial engineering and quality control. By optimizing trimming parameters and validating them through rigorous analysis, Kamaya Electric has proven that innovation need not always come from external investment it can be driven from within, through knowledge, teamwork, and the smart application of engineering principles. This project is a testament to the potential for sustainable, data-backed growth in the manufacturing sector and sets a strong precedent for future improvement initiatives across the organization.

APPENDIX

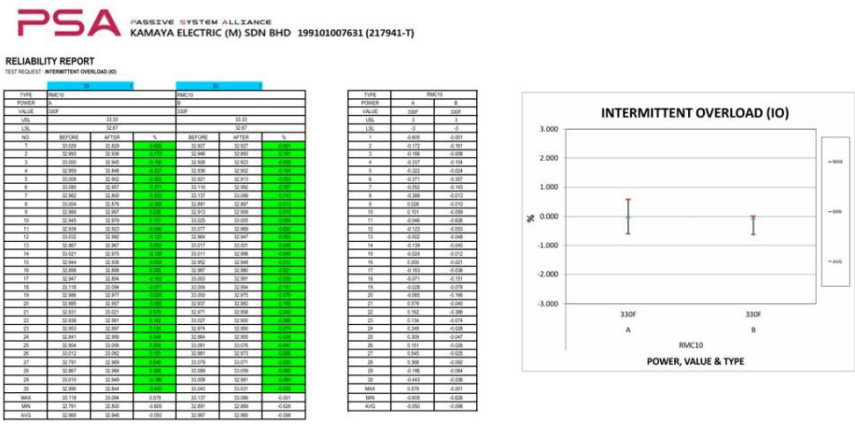
Current Noise (CN): Pass



Short Time Overload (STO): Pass



Intermittent Overload (IO) : Pass



Summary:

PASSIVE SYSTEM ALLIANCE
KAMAYA ELECTRIC (M) SDN BHD 199101007631 (217941-T)

RELIABILITY REPORT

NO	TYPE	OTHER	VALUE	CN	SPEC (dB)	STO	SPEC (%)	IO	SPEC (%)
1	RMC10	A	330F	PASS	15	PASS	±1	PASS	±3
2		B	330F	PASS	15	PASS	±1	PASS	±3

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Monitoring Fix Time Delivery

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ABSTRACT

In order to improve logistics operations and inventory management efficiency, this study focuses on Company XYZ's deployment of the Fixed Time Delivery (FTD) system. Manufacturing company XYZ has been dealing with supplier delivery delays on a regular basis, which has led to stock shortages and delays in customer order fulfillment. The main objective of this study is to reduce inconsistencies in supplier deliveries by ensuring that at least 70% of suppliers comply with the fixed delivery schedule. To address these challenges, the FTD system was introduced to restructure delivery timelines and strengthen supplier commitment. A quantitative research approach was employed, involving the systematic collection and analysis of delivery data to assess the effectiveness of the system. The findings showed a significant improvement in on-time delivery performance, with more than 70% of suppliers adhering to the fixed schedule. In addition, the system helped reduce congestion at the factory entrance, improved unloading processes, and enhanced material handling. With the use of a digital platform (Airtable), real-time monitoring was made possible, allowing for quicker issuance of notices and faster responses to delay issues. Overall, the FTD system has led to more efficient logistics operations, reduced inventory costs, and improved coordination, thereby creating a more systematic and professional working environment.

Keywords: Supplier delays, Inventory management system, Fixed Time Delivery (FTD), Airtable platform, Delivery schedule adherence

1.0 INTRODUCTION

1.1 Fix Time Delivery

Fix Time Delivery (FTD) is one of the important concepts in logistics and supply chain management because it involves the delivery of goods at a precisely set time. In the FTD system, delivery times are critical and must be strictly adhered to by suppliers. This is to ensure that the work flow and production process are not interrupted. Just-in-time delivery can help reduce storage costs, optimize inventory space and maintain continuity in operational processes.

The FTD concept is particularly relevant in manufacturing industries such as automotive, where components need to be delivered on time to ensure the assembly process runs smoothly without interruption. Manufacturers who use the Just-In-Time (JIT) method rely heavily on FTD to ensure that materials arrive at the right time because they are not too early or too late to avoid overstocking or material shortages.

FTD will be used to ensure that Child Part Store (CPS) receives goods from suppliers at certain hours every day and suppliers need to update the procurement department in case of failure or want to make an emergency delivery. Suppliers who fail to comply with the established time will affect the entire production chain and cause delays and disruptions to the manufacturing process. Therefore, supplier performance will also be evaluated based on the extent to which they comply with FTD through Supplier Scoreboard.

1.2 Evaluation Process

Interface and Supplier Scoreboard evaluation is done based on criteria:

i. Punctuality of Delivery – Review / remark of the delivery record to ensure that the delivery is carried out according to the schedule that has been set.

1.3 Problem Statement

Company XYZ faces constant challenges in maintaining the effectiveness of delivery on time due to delivery delays from suppliers. These delays result in inventory shortages in store, which not only prevents the company from fulfilling customer orders on schedule, but also affects the operation of the entire supply chain. In response, suppliers often send a recovery plan with additional stock deliveries in an effort to replace delayed items. However, these turnaround plans often result in over-shipping from suppliers, resulting in excess inventory in Company XYZ store. This excess stock creates new problems, including increased storage costs, store space congestion and difficulties in stock flow management. This situation burdens the company's inventory management system, causes additional delays in processing new orders, and further affects Company XYZ 's ability to meet on-time delivery commitments to customers. In addition, repeated delays from suppliers and inconsistent recovery plans also affect operational efficiency and damage the company's relationship with customers which expect on-time delivery. This whole situation calls for better coordination between Company XYZ and suppliers in terms of inventory planning and logistics to avoid delivery delays and ensure delivery on time can be met consistently.

1.4 Research Objective

i. To achieve timely deliveries by ensuring that 70% suppliers adhere to fixed delivery schedules.

1.5 Research Scope

i. Database and supplier scoreboard for visual management.

1.6 Literature Review

The concept of Fixed Time Delivery (FTD) plays a critical role in modern supply chain management due to its ability to optimize inventory levels and minimize storage costs. By aligning delivery schedules closely with production requirements, FTD systems reduce the dependency on extensive warehousing and mitigate wastage. This delivery strategy closely aligns with the Just-In-Time (JIT) philosophy, which emphasizes lean operations by ensuring that materials and components arrive only when needed. As discussed in *SupplyChainBrain* (2023), this approach is instrumental in minimizing excess inventory and maintaining operational agility.

According to Jie Yang et al. (2021), successful JIT implementation depends heavily on real-time demand signals and a high level of supply chain integration. The synchronization of timely deliveries, accurate planning, and responsive logistics supports businesses in avoiding both overstock and stockouts. This ensures cost efficiency and enables companies to remain competitive in dynamic market conditions while effectively managing risks associated with supply chain disruptions. To support the FTD approach and reinforce delivery efficiency, many organizations have adopted the Supplier Scoreboard as a performance monitoring and incentive tool. The Supplier Scoreboard allows companies to evaluate suppliers systematically based on criteria such as delivery punctuality, order accuracy, and responsiveness to production needs. This practice helps to maintain service quality and bolsters customer confidence in a company's logistical reliability.

As emphasized by P. Giovanni (2021) in the article *Smart Supply Chains with Vendor Managed Inventory, Coordination, and Environmental Performance*, the integration of digital systems into supplier management significantly enhances collaboration, reduces lead times, and introduces structured performance tracking mechanisms. These systems play a crucial role in promoting data-driven decisions and continuous improvement initiatives**.** In terms of digital tools that support supplier and inventory management, Airtable has been recognized for its flexibility and integration capabilities. As noted by A. Caruso et al. (2023), Airtable provides diverse data field options including text, numbers, dates, and attachments, which make it versatile for supply chain documentation. Furthermore, A. Hammond et al. (2023) highlighted that Airtable facilitates full access to historical data, supports automation, and enhances workflow efficiency by enabling integration with third-party tools.

Maintaining consistency in FTD and overall supplier performance also requires robust relationship management. This can be achieved through regular communication, clear expectation setting, and the implementation of strategic incentives or penalties to encourage compliance. As stated by OpenBOM (2023)**,** open dialogue and collaborative improvement plans are essential in motivating suppliers to meet or exceed standards and ensuring consistency in supply chain operations.

2.0 Methodology

This research uses a quantitative approach to investigate the FTD system. The chosen research design is a case study, which allows me to collect comprehensive data and test the effectiveness involving punctuality of delivery and product quantity. A questionnaire was created to obtain supplier consent and this research uses the DMAIC research instrument in contributing to a broader understanding of inventory management problems in the company. Therefore, work process planning and Gantt charts are needed to assist in the implementation of this project. Figure 2.1 shows the process flowchart of the research project.

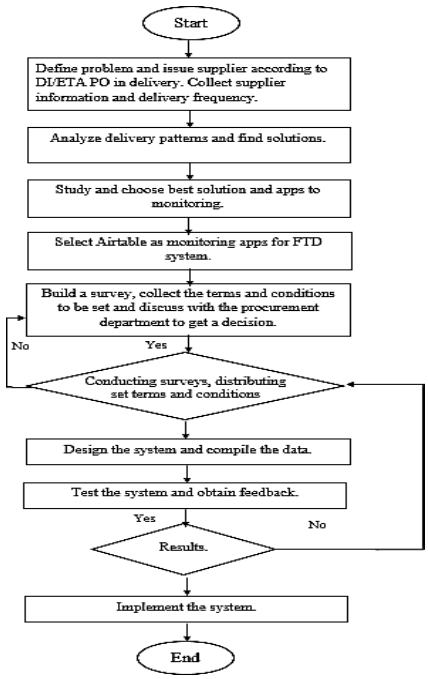


Figure 2.1: Process flowchart of the research project

2.1 Goods Receipt Report

Record the details of receipt of goods such as date, time and quantity of the goods in the receipt report. This can be compared with the DI/ ETA PO that has been set. Figure 2.1 shows the goods receipt report.

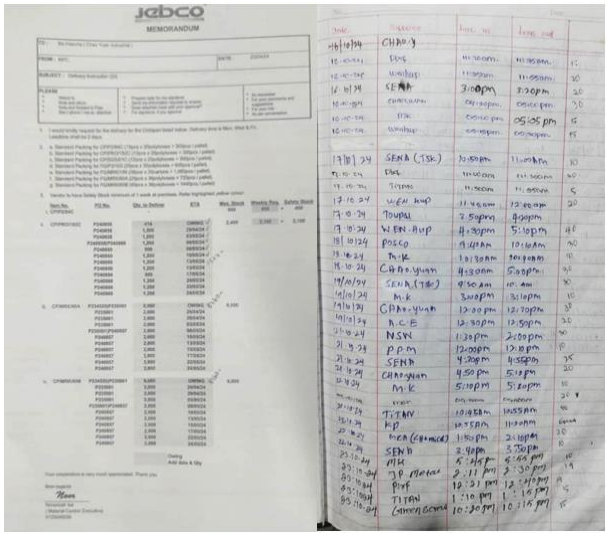


Figure 2.2: Goods receipt report

2.2 Possible Restrictions and Ethical Issues

1. Limitations:
   Suppliers may face time and capacity constraints in meeting fixed delivery dates due to limited resources, high demand or difficulties in logistics.

2. Ethical considerations:
   Forcing suppliers to meet tight schedules without considering their capabilities can be considered unethical as it can cause an unbalanced workload, compromise worker safety or lead to violations of workers' rights if suppliers are forced to use excessive overtime.

2.3 Research Instrument

This project uses a data record guide and a structured survey as the main research instruments. This instrument works in surveys to measure the time density of receiving goods and storage arrangements, in addition to gathering factual information about experiences, difficulties, and suggestions from users.

2.4 DMAIC

For the method in the implementation of this project, I would like to use the DMAIC technique to solve the problem. DMAIC is one of the structured problem-solving methods within the Six Sigma framework that aims to improve overall process effectiveness by reducing variation and defects. The acronym DMAIC refers to the five main phases in its implementation, namely Define, Measure, Analyse, Improve, and Control. Each phase is designed to ensure a deep understanding of the problem at hand, identify root causes that cause variation or defects in the process, and devise effective and sustainable solutions. Through this systematic approach, organizations can improve operational efficiency, improve product or service quality, and at the same time, reduce costs and improve customer satisfaction. DMAIC is not only a problem-

solving tool but also a strategic approach to drive innovation and process transformation to a higher level. Figure 2.3 shows the DMAIC method.

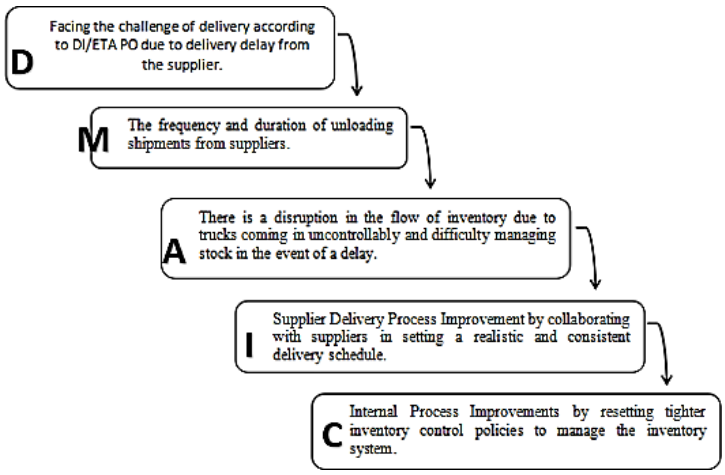


Figure 2.3: DMAIC method

2.5 Sample Communication and Survey Question

This communication aims to introduce the FTD system to suppliers, discuss the agreement and ensure their understanding and readiness in meeting the delivery needs of XYZ. This communication uses email assistance. FTD is a delivery system that ensures punctuality according to the set schedule. This approach not only improves the efficiency of the supply chain, but also helps to smooth the daily operations of the company. We believe that the implementation of FTD will add value to the cooperation between XYZ and suppliers. As a next step, we would like to discuss further on the implementation of FTD, including the conditions, benefits, and mutual responsibilities. We hope that the supplier can provide full support by adhering to the set delivery schedule.

We greatly appreciate the cooperation provided by the supplier in ensuring that deliveries are carried out consistently and on time. Through this joint effort, we are confident that the implementation of FTD can be successful and provide benefits to both parties. From the communication and questionnaires conducted with suppliers I can conclude that the majority of suppliers show a high level of commitment in adhering to the fixed delivery schedule set by the company. This result forms the basis for my main objective, which is "To achieve on-time delivery by ensuring that 70% of suppliers adhere to the fixed delivery schedule." The following are the main reasons that support this objective:

i. Majority agrees to FTD:
A total of 83.3% of suppliers agree to adhere to the FTD, showing that they understand the importance of the fixed delivery schedule which is critical to the smooth running of the company's operations.

ii. Delivery frequency:
Although there are delivery delays as shown in the chart, they are not considered critical as most of the delays are still within the acceptable time range.

2.6 Sample Communication and Survey Question

Data analysis will be done to interpret the collected data and extract key insight

1. Factual Information Analysis.
   This analysis aims to identify information that contains facts or events that occurred and can be proven objectively through data collection.

2. Quantitative Data Analysis.
   Survey responses will be summarized and analyzed using descriptive statistics, such as frequency, time, and quantity. This will enable a quantitative assessment of user satisfaction and system effectiveness.

2.7 FTD Implementation Procedure Using Airtable

To ensure that the implementation of FTD runs more systematically and systematically, Airtable is used as a delivery monitoring and management platform. The steps for its use are outlined below and illustrated in Figure 2.4.

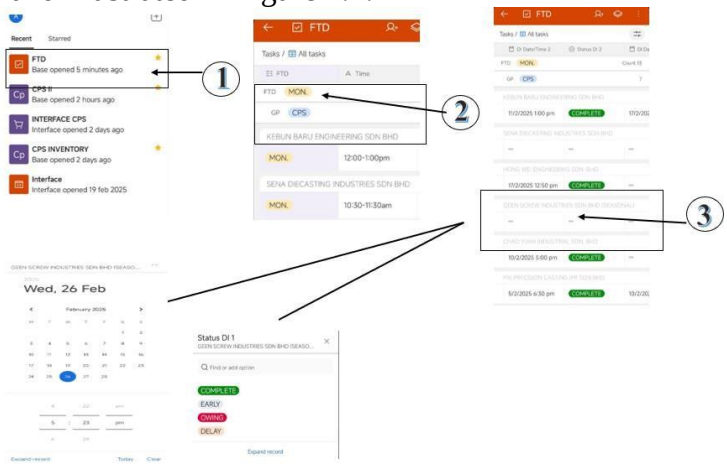


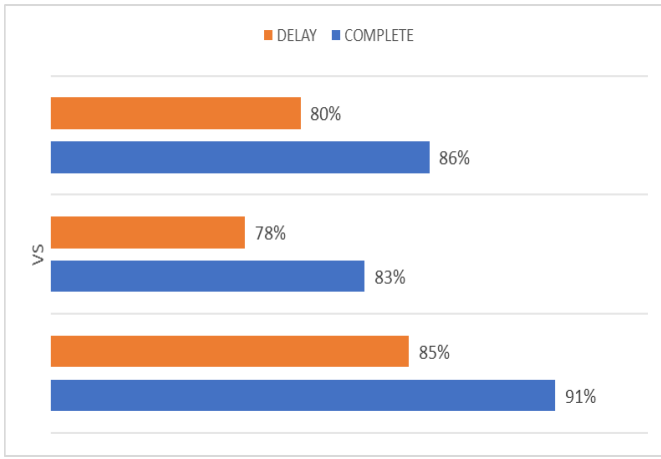
Figure 2.4: Working Instructions for Using Fix Time Delivery (FTD) In Airtable

1. Operators need to click on the FTD sheet in the Airtable application.
2. FTD Data Review.
   - Check the FTD schedule for the date and time set, group of items, and supplier's name based on the DI / ETA PO.
   - Ensure that each delivery is recorded according to the actual time of arrival and compared to the original schedule
3. Filling in Confirmation Data & Follow-up Actions.
4. Handling of Supplier Arrival Early Cases.
   - If the supplier arrives earlier than the set FTD schedule, the delivery is still considered complete and is not counted as a delay.
5. Completion and Exit from the Application.

3.0 RESULTS AND DISCUSSION

The implementation of an inventory management system based on Fixed Time Delivery (FTD) using Airtable has demonstrated significant improvements in inventory control and logistics management. The system ensures that operations are aligned with the established execution plan while enabling real-time monitoring to enhance both efficiency and accuracy.

The integration of Airtable allows for immediate tracking of incoming goods, reducing the risk of stock loss and promoting a more structured and efficient inventory management process.



	DELIVERY	DELAY (2024) OCT	NOV	DEC	FTD (2025) JAN	FEB	MAR	APRL
	1	1	1	1	1	1	1	0
	1	1	1	1	0	0	0	0
PLT	1	1	1	1	1	1	2	1
	1	1	1	1	1	2	0	1
PPLIES SDN	1	1	1	1	0	3	1	1
BHD	12	10	8	12	6	5	7	7
SDN BHD	1	1	1	1	1	1	1	1
	1	1	1	1	0	0	1	1
	1	1	1	1	1	1	0	1
	0	0	0	0	0	0	1	0
	4	4	3	2	1	2	0	2
	1	1	1	1	1	1	0	0
	4	4	3	2	0	1	3	1
HD	1	1	1	1	2	3	2	1
	12	11	10	7	0	0	0	2
)	1	1	1	1	0	0	0	1
BHD	4	3	2	2	1	0	1	1
	4	4	3	1	1	1	1	1
	1	1	1	1	0	0	0	0
N BHD	0	0	0	0	1	1	0	1
BHD	0	0	0	0	4	5	12	7
	1	1	1	1	1	1	0	0
L SDN BHD	0	1	1	1	0	0	0	0
	8	7	5	6	2	1	3	0
	1	1	1	1	0	0	0	0
N BHD	12	10	12	9	5	5	5	7
	1	1	1	1	0	2	1	1
	1	1	1	0	1	1	1	2
	4	4	3	4	1	2	1	0
	1	1	1	1	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
DN BHD	8	6	4	7	4	5	2	6
	1	1	0	1	0	0	0	0
BHD	1	1	1	1	1	0	1	1
HD	1	1	1	1	0	1	0	0
	1	1	1	1	0	0	0	0
	1	1	1	1	0	0	0	1
SDN BHD	12	10	9	11	6	5	6	5
BHD	1	0	1	1	0	0	1	0
NG SDN BH	4	3	2	3	3	7	3	7
DN BHD	4	4	2	2	3	1	0	0
	0	0	0	0	0		1	1
DN BHD	8	6	7	6	3	0	0	1
S SDN BHD	12	8	9	11	6	7	8	8
	0	0	0	0	1	0	0	0
D	4	3	3	2	1	1	0	0
Y SDN BHD	1	1	1	0	0	1	1	1
D	8	7	5	8	4	4	5	4
	1	0	1	1	1	1	0	1
	0	0	0	0	1	1	0	0
HD	8	6	7	5	4	11	12	14
SDN BHD	12	10	9	11	4	8	6	6
	1	1	1	1	1	1	1	1
	172	147	134	138	77	96	93	99

Figure 3.1: Difference in delivery rates before and after FTD system

Based on Figure 3.1, it can be seen that there is a significant difference between the delay rate and delivery completion rate before and after the implementation of the FTD system. Before the implementation of FTD, XYZ faced a high rate of delivery delays, which was between 78% to 86%, while the rate of successful delivery completion according to schedule only reached around 83% to 91%. This delay rate occurred due to the absence of a systematic delivery scheduling system and follow-up actions from the supplier when delays occurred.

Figure 3.2: FTD time schedule and sample implementation data

After the implementation of FTD, deliveries are carried out according to predetermined time slots agreed upon by the company and the supplier, resulting in a more structured and systematic process. As shown in Figure 3.1, the FTD time schedule and sample

implementation data illustrate this improvement. The system helps reduce congestion, enables real-time monitoring, and enhances both the efficiency and accuracy of logistics operations. Additionally, supplier compliance with delivery schedules has improved, allowing the company to objectively evaluate their performance.

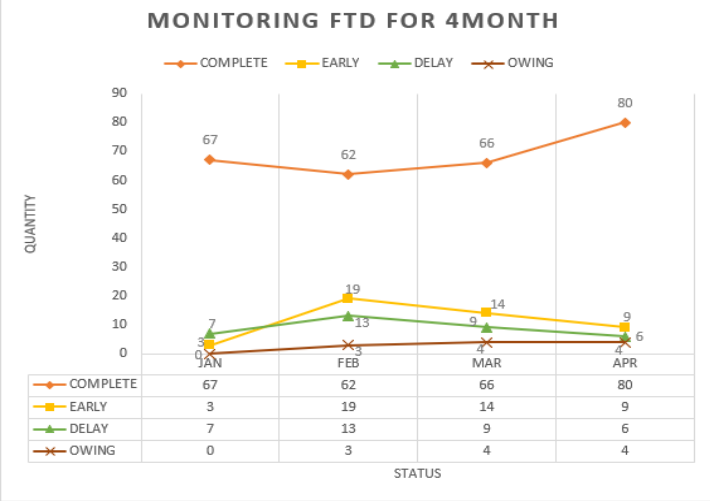


Figure 3.3: FTD Delivery Performance Over a Four-Month Period (January–April)

Following the implementation of the FTD system, its effectiveness is demonstrated in Figure 3.3, which shows that over a four-month data collection period, performance consistently exceeded 70% of the set target. This indicates that deliveries were highly optimized according to the capacity of the delivery trucks. Unnecessary trips were consolidated, reducing delivery frequency without compromising the quantity of goods required. Demand continued to be fully met, with no issues of overstocking or stock shortages. Additionally, the company took the initiative to provide a pickup service for selected suppliers using the milk run system, further supporting the successful implementation of the FTD system.

Suppliers were considered FTD-compliant when deliveries were made on time, with any early or late arrivals properly recorded during emergencies, and when deliveries adhered to the instructions stated in the Delivery Instruction (DI) and Estimated Time of Arrival Purchase Order (ETA PO). Non-compliant suppliers were identified based on repeated late deliveries and instances of short shipments, which negatively impacted supply planning accuracy.

Moreover, this approach ensured that every item delivered was pre-verified against the DI/ETA PO, preventing the delivery of items not required for the weekly production schedule. Overall, the implementation of the FTD system has not only contributed to smoother delivery and receiving processes but also strengthened logistics control and enhanced supply chain management in a more efficient and organized manner.

4.0 CONCLUSION

Based on research conducted on the implementation of the FTD system at Company XYZ, it can be concluded that the system has significantly improved the efficiency of logistics operations and supply chain management. The FTD approach not only increased the on-time delivery rate but also helped reduce excess inventory, which previously disrupted workflows in both the store and production areas. Data analysis showed that after the introduction of FTD,

over 70% of suppliers adhered to the agreed delivery schedule. The system successfully reduced the number of monthly deliveries from 172 to fewer than 100 by leveraging accurate forecasting, structured planning, and better control of incoming stock based on fixed delivery days, times, and safety stock levels. This organized scheduling improved supplier discipline, minimized bottlenecks, and enhanced overall operational efficiency.

Improved compliance also led to fewer delays, reduced congestion at Gates 5 and 7, and higher customer satisfaction. Additionally, FTD helped ease staff workload by assigning specific time slots for supplier truck unloading, which optimized traffic flow within the company. The use of the Airtable platform as the core monitoring tool further strengthened the system. It enabled real-time data access, allowing for faster and more effective corrective actions in case of delays. With features such as filtering, organized data views, and structured dashboards, management can objectively evaluate supplier performance through the Supplier Scoreboard, fostering more transparent, sustainable, and collaborative relationships.

ACKNOWLEDGMENT

This project, which focuses on monitoring Fixed Time Delivery (FTD), has brought a sense of satisfaction and success to our team. I would like to express my deepest appreciation to my Polytechnic supervisor, Puan Nazihah binti Mohd Noor, for her unwavering guidance, mentorship, and encouragement throughout the research and implementation of this project. Her thoughtful feedback and constructive advice played a vital role in refining and enhancing the quality of the study. My heartfelt thanks also go to my industrial mentor, Puan Norazizah binti Isa, for her continuous support, guidance, and patience throughout the course of this project. Her valuable insights and suggestions were crucial in ensuring that the project met its intended objectives. I would also like to extend my gratitude to all suppliers and stakeholders involved in this project. Their cooperation in adhering to the Fixed Time Delivery (FTD) schedule was essential to the success of the implementation. Their commitment and professionalism are deeply appreciated.

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Optimization Of Jig Stacking Machine For Increase Productivity

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ABSTRACT

This project aims to optimize the jig stacking machine to improve productivity in the manufacturing of the 0805 product. The current configuration restricts output to roughly 528 million units monthly, although the objective is 600 million units, leading to inefficiencies, extended handling durations, and challenges in fulfilling production requirements. To address these challenges, the study implemented Lean Six Sigma methodologies, specifically the DMAIC framework, and employed tools such as fishbone diagrams, and fault tree analysis to identify root causes and operational bottlenecks. The research aimed to reduce time losses during substrate supply travel and to achieve at least a 10% improvement in productivity. Machine parameters were systematically modified and tested to ensure compatibility with the 0805 product. The improved configuration exhibited substantial enhancements, with machine performance rising by 47% post-implementation, attributed to an average productivity of 38.56% over a three-month evaluation period. Additionally, waste related to delays and defective components was minimized, contributing to a more efficient and reliable production line. The findings highlight the effectiveness of targeted machine optimization in improving manufacturing performance. This project not only improves operational efficiency but also supports the broader goals of smart manufacturing and Industry 4.0 by aligning traditional equipment with data-driven process improvements.

Keywords: Machine Optimization, Jig Stacking, Lean Six Sigma, Productivity, 0805 product.

1.0 INTRODUCTION

In today's highly dynamic manufacturing sector, maintaining efficiency and meeting rising production demands have become increasingly challenging, especially with the shift toward Industry 4.0. As manufacturers move toward digital transformation and smart technologies, there is growing pressure to optimize traditional processes while ensuring precision and quality. Industry 4.0 encourages the integration of data-driven tools, automation, and intelligent systems to enhance operational flexibility and productivity (Gherghea, Bungau, & Negrau, 2019).

At Company X, Factory A, the S2 production line was found to be underperforming, primarily due to inefficiencies in the jig stacking machine responsible for assembling 0805 components. These components are particularly small and delicate, requiring precise alignment and timing to ensure consistent quality. When early assessments were conducted, significant issues were observed, including delays during substrate handling, irregular sensor timing, and inconsistent placement. These recurring problems contributed to machine downtime and reduced monthly output.

To address these challenges, this project implemented a structured problem-solving approach using Lean Six Sigma methods. Specifically, tools such as the DMAIC framework, Fishbone Diagram, and Fault Tree Analysis were applied to uncover the root causes behind the reduced performance. This methodology has been proven effective in various industrial

setting where process improvement and productivity gains are needed (Clarence & Mat Daud, 2020; Mekala et al., 2020).

Through a combination of field observations, data analysis, and feedback from machine operators, it became clear that the vacuum system's delays and misaligned components were causing disruptions in the stacking cycle. After a series of parameter adjustments including sensor recalibration and mechanical part replacement the system showed clear signs of improvement. These changes not only boosted machine output but also aligned with broader manufacturing trends that emphasize smarter, more reliable production systems (Sivasankaran, Radjaram, & Karthigayan, 2020).

The result of study present the effectiveness of the optimization efforts. Monthly machine output increased from 528 million pieces in October 2024 to over 766 million pieces in January 2025, marking a productivity increase of 38.56% and machine performance up to 47%. This validated the project's primary objective: identifying and resolving the underlying issues in the jig stacking process to support sustained production improvements. The findings not only demonstrate the importance of root cause analysis in industrial settings but also reinforce the role of smart process optimization in achieving manufacturing excellence.

i. Gap Substrate

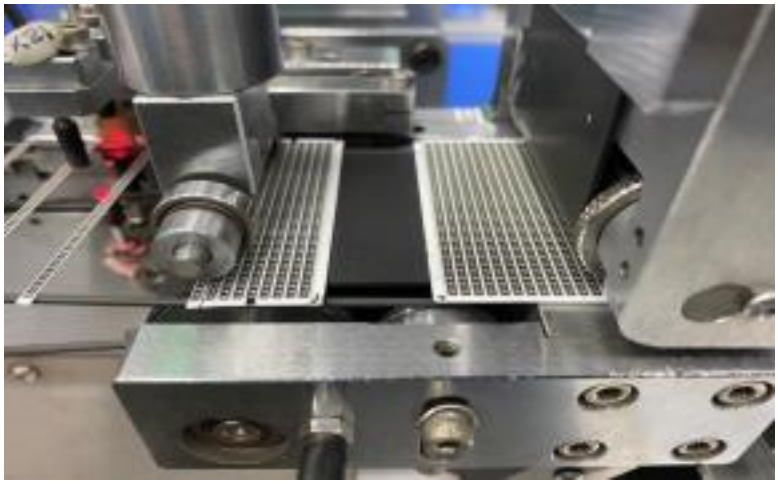

Figure 1: Current Gap Substrate

1.1 Problem Statement

Due to the limitation of the distance between the substrate sheets used in the separation process between the upper and lower breakers, the manufacturing process of 0805 Type 20 products of Company X is currently experiencing significant productivity constraints due to high demand from customers. Since the existing machines can only handle small production and do not meet the targets set by management. As a result, even though the demand for the product is increasing, the highest daily output that can be achieved is 528 million pieces while the minimum target is 600 million pieces.

This constraint not only reduces productivity but also increases operational workload, increasing the time and handling of the production process. Adding machines will result in high production costs and additional space required to place them which may result in rework. Its ability to meet production goals, shorten cycle times and make full use of its workforce and

equipment capacity is limited by these inefficiencies.

Investigating existing vacuum supply times and understanding how these constraints affect overall production efficiency is essential to overcoming these problems. A critical first step in creating workable solutions that can reduce substrate spacing, reduce process time waste, and increase productivity without sacrificing equipment compatibility or product quality is recognizing these constraints.

1.2 Research Objective

To identify the problem at jig stacking process for 0805 Type 20 products, with the aim of identifying how these limitations affect production efficiency, run time and output quality. The investigation focused on understanding the causes of inefficiencies related to sensor timing, substrate spacing and manual handling during production. The goal was to gather accurate data and operator insights that could support machine modifications that increase productivity while maintaining compatibility with existing equipment.

2.0 METHODOLOGY

In manufacturing process improvement, identifying the real source of a problem is crucial. Several tools are commonly used for this purpose. The Fishbone Diagram, often called the cause-and-effect diagram, helps organize potential causes of a problem into categories like manpower, machinery, method, and materials, making it easier to visualize contributing factors. Fault Tree Analysis (FTA) takes a different approach by starting from the top looking at a failure and working downward to map out possible causes in a logical sequence. Another widely used method is DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. It offers a structured, step-by-step process to find and eliminate inefficiencies using data. Additionally, the 5 Whys technique simply involves asking “why” multiple times until the root cause becomes clear. When used together, these tools offer both broad and detailed perspectives that help uncover hidden issues and guide effective solutions in real production settings (Nallusamy & Saravanan, 2016; Shah & Patel, 2018).

3.0 RESULTS AND DISCUSSION

The results of this study confirm that delays in substrate supply and sensor misalignment were the primary contributors to low productivity in the jig stacking process. These problems were verified through triangulated data sources: machine logs, operator interviews, and observation. Mechanical wear further compounded the inefficiencies, leading to strip rejection and high operator intervention. By identifying these issues, the study laid the groundwork for targeted machine improvements that ultimately resulted in a 38.56% average productivity increase over a three-month monitoring period. The findings validate the use of structured problem-solving tools such as Fishbone Diagram and Fault Tree Analysis in manufacturing settings. The systematic identification of root causes enabled meaningful machine improvements and more stable process output.

3.1 Production Output Performance

The performance of the machine was analyzed before and after the evaluation process, using monthly output in kk pieces (kpcs) as the performance metric. Figure 2 illustrates the machine output over a four-month period from October 2024 and then from January 2025 to March 2025, with October data representing pre-evaluation performance and the subsequent months representing post-evaluation results.

Table 1: Monthly Output of 0805 Type 20

Month	Target (pcs)	Total Output (pcs)	Remarks
OCT	600000000	528,123,000	Below target
JAN	600000000	766,437,755	Target achieved
FEB	600000000	670,404,322	Target achieved
MAC	600000000	758,460,747	Target achieved

i. Monthly Production Output

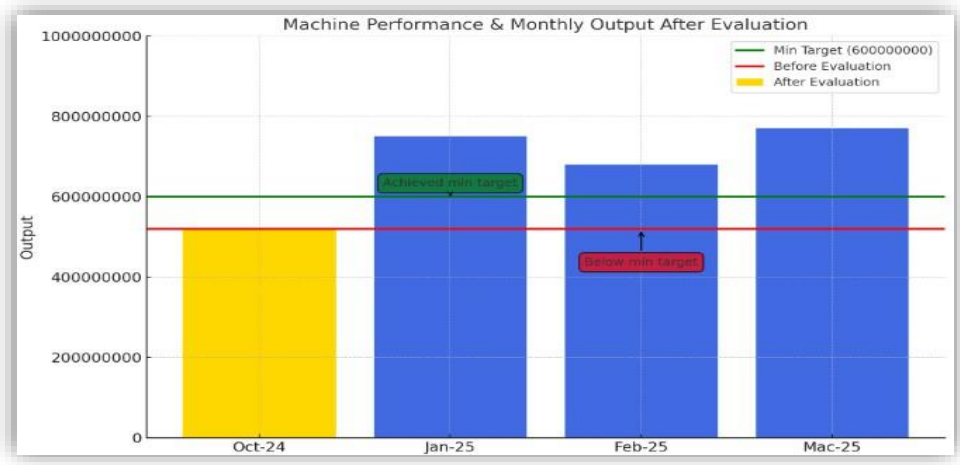

Figure 3.1 : Monthly Production Trend of 0805 Type 20

Before the evaluation on October 2024, the machine output was significantly below the targeted minimum monthly threshold of 600,000,000 pcs, with a recorded value of approximately 528,123,000 pcs. Following the evaluation, a remarkable improvement in machine output was observed. In January 2025, the output scored to 766,437,755 pcs clearly surpassing the set target. This indicates an immediate and strong positive impact of the evaluation measures on machine productivity.

However, in February 2025, the output achieves to meet the monthly minimum of 600,000,000 pcs which is 670,404,322 pcs. This improvement indicates that the improvement is significant, maintaining consistent performance as well as ongoing monitoring and possible further optimization. By March 2025, the machine regained its improved output level, once again achieving approximately 760,000,000 pcs, which is above the target.

3.2 Impact After Improvement

The identification of the key problems in the jig stacking process led to the implementation of targeted corrective actions, which had a significant positive impact on the overall performance of the jig stacking machine. One of the most notable outcomes was the substantial increase in monthly production output. Prior to the improvements, the machine consistently underperformed, producing only 528 million pieces per month, well below the target of 600 million pieces. After implementing the necessary adjustments particularly to the vacuum supply delay, sensor timing, and mechanical components the output rose to 766 million pieces in January 2025 and remained above target in the following months. This represents an average

productivity increase of 38.56% over a three-month period, indicating that the corrective measures were not only effective but also sustainable.

ii. Effect time of Gap Reduction

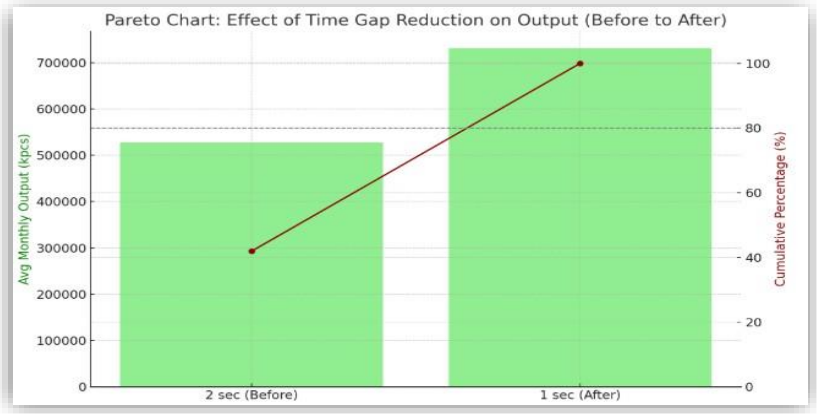

Figure 2.2: New Time Gap

Additionally, machine downtime and operational delays were significantly reduced. The vacuum system, which previously caused timing interruptions during substrate supply, was optimized, resulting in smoother and faster handling of substrates. Likewise, recalibrating the sensors improved alignment accuracy, minimizing the occurrence of gaps between substrates and reducing instances of reverse or misaligned strips. These enhancements led to a noticeable reduction in rework and defects, as confirmed by operator feedback through the "Cho Ko Tei" check sheet. Furthermore, mechanical parts such as the breaker belts and substrate traveller, which had shown signs of wear, were replaced to restore mechanical stability and reduce vibrations during the stacking process.

The improvements also contributed to better operator efficiency. With fewer machine errors and less need for manual intervention, operators were able to focus on process monitoring rather than constant troubleshooting. This reduced workload created a more productive and less error-prone environment. Additionally, the integration of monitoring tools and performance tracking, such as the use of checklists and data logs, enabled more proactive maintenance. This ensures that potential issues can now be detected and addressed early, before they escalate into major faults.

In conclusion, the improvements made after identifying the core problems in the jig stacking process directly addressed the inefficiencies that were limiting performance. The successful resolution of these issues led to increased productivity, improved product quality, more stable operations, and a more efficient workforce. These impacts validate the importance of problem identification as a critical first step in any process improvement initiative and highlight the effectiveness of using a structured, data-driven approach in high-precision manufacturing environments.

3.3 Operator Feedback

Operator feedback as shown at figure 3 played a crucial role in evaluating the effectiveness of the jig stacking machine optimization. Throughout the testing and implementation phase, operators were provided with 'Cho Ko Tei' forms to document their observations, challenges, and overall impressions regarding machine performance before and after parameter adjustments. The majority of operators reported noticeable improvements in machine responsiveness, reduced delays during substrate supply travel, and smoother alignment of components.

i. *Cho ko Tei* Feedback

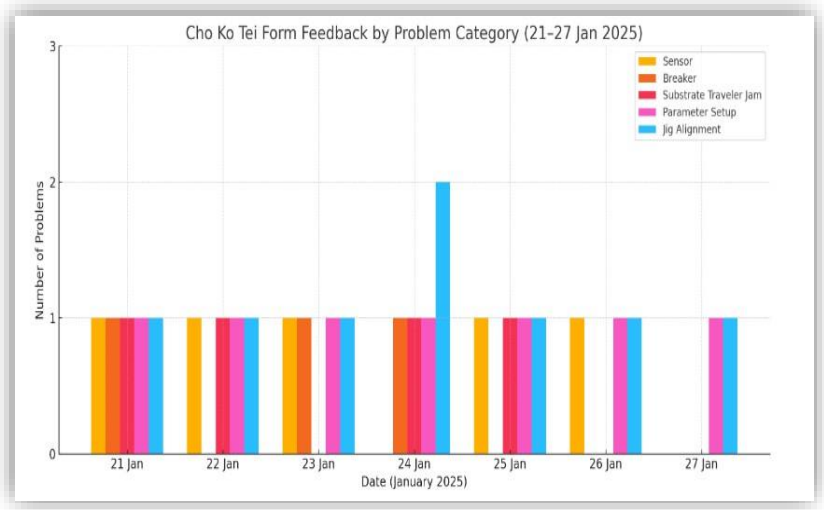

Figure 3.3: Cho ko Tei Feedback

Furthermore, they highlighted that the optimization led to fewer interruptions, minimized rework, and enhanced output consistency. Some feedback also noted improved ease of operation and reduced need for manual intervention, which contributed to better workflow efficiency. However, a few operators suggested additional enhancements, such as further refinement of sensor timing and clearer visual indicators for machine status. Overall, the feedback confirmed that the changes positively impacted production efficiency and supported the project's objective of increasing productivity through machine optimization.

3.4 Limitations of the Study

This study, while successful in optimizing the jig stacking machine for improved productivity of the 0805 product, faced several limitations that must be acknowledged. Firstly, the scope of the research was limited to the S2 production line at Company X, which means the findings may not be applicable to other production lines or products that utilize different equipment configurations. Additionally, the optimization was specifically designed for the 0805 component, and therefore, the parameter settings and adjustments made may not yield the same results when applied to other product sizes or types. The performance evaluation was conducted over a relatively short period of three months, which, although it demonstrated positive outcomes, did not allow for assessment of long-term sustainability or the impact of equipment wear and operational variations over time.

Moreover, the study relied primarily on manual data collection methods such as operator feedback, observational analysis, and machine output records. The absence of real-time data monitoring systems may have limited the precision and depth of the performance insights obtained. Operator feedback, while valuable, introduced a level of subjectivity that could influence the consistency and accuracy of the findings. Resource constraints also played a role in limiting the scope of machine modifications; only minor physical adjustments, such as sensor timing and part replacements, were implemented. More advanced improvements, including automation or integration with smart monitoring technologies, were not feasible within the available time and budget. Furthermore, external variables such as supply chain disruptions, machine downtime, and operator changes were not controlled and may have affected the reliability of the production data collected. Despite these limitations, the study provides a strong foundation for future improvements and highlights key areas for further investigation to enhance manufacturing efficiency and machine reliability.

4.0 CONCLUSION

In conclusion, this project successfully addressed the productivity issues faced in the jig stacking process at the S2 production line of Company X specifically for the manufacturing of the 0805 component. By applying Lean Six Sigma principles and utilizing tools such as the DMAIC framework, fishbone diagram, and fault tree analysis, the root causes of low productivity such as delays in substrate supply, inefficient vacuum settings, and sensor timing were systematically identified and addressed. Through parameter optimization and targeted machine adjustments, the study achieved a significant improvement in overall machine performance.

The evaluation results demonstrated a notable increase in productivity, with machine output rising by approximately 38.5% over a three-month post-implementation period, surpassing the original monthly production target of 600 million pieces. Additionally, the project successfully minimized machine downtime, reduced waste caused by delays and defects, and improved the reliability of the jig stacking process. These outcomes not only validated the effectiveness of the proposed solutions but also contributed to aligning the production system with Industry 4.0 principles, emphasizing data-driven optimization and continuous improvement.

Overall, the findings from this study underscore the importance of process analysis, parameter tuning, and cross-functional collaboration in enhancing manufacturing efficiency. While the scope was limited to a specific product and production line, the methods and results serve as a valuable REFERENCES for future efforts aimed at improving machine-based processes within the broader manufacturing environment. Future research can expand upon this foundation by integrating smart sensors, real-time data analytics, and predictive maintenance systems to further elevate performance and adaptability in high-volume production settings.

ACKNOWLEDGMENT

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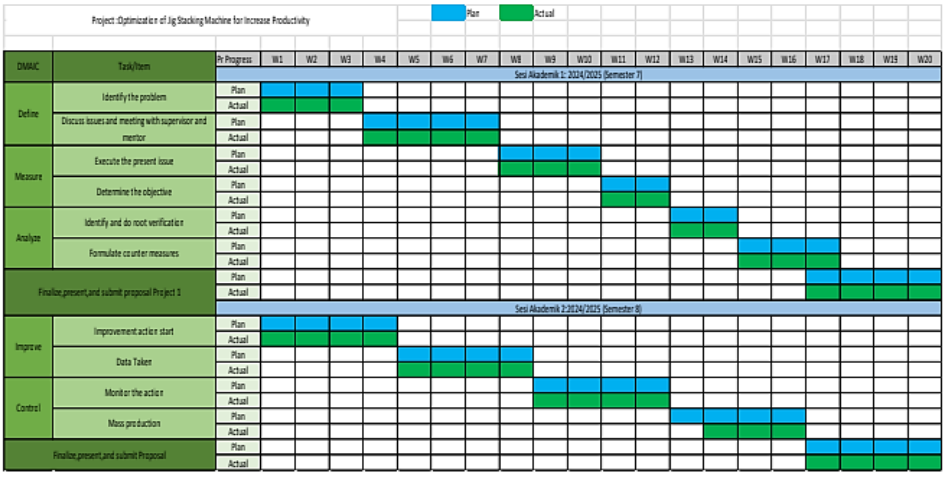
successful execution of this project. The opportunity to learn in a real industrial environment has been an invaluable experience. Finally, I wish to express my sincere gratitude to my supervisor from the Polytechnic, Puan Nazihah binti Mohd Noor for the constructive feedback, consistent guidance and encouragement throughout the course of this project. Their mentorship has played a vital role in shaping the outcome of this research.

Thank you all for your contributions, support and belief in my efforts.

APPENDIX

i. Gantt Chart



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Optimizing Paste Waste at P10 Printing Process by Using Recycled Paste

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ABSTRACT

This study presents a project by the Production Department to improve the Resistive Layer Printing (RLP) process, focusing on the P10 printing stage. The goal is to reduce waste of paste 1025 by reusing leftover paste. The project addresses cost and efficiency issues by testing if the recycled paste can still meet product quality and process standards. The main issue found was high paste wastage during the P10 process, which increased production costs and reduced material efficiency. This happens because the leftover paste from the upper overcoat printing is usually discarded after the process is completed. This is because after the process has finished, the remaining paste will be considered non-reusable. The objective of this project is to identify solutions for a comprehensive paste waste reduction strategy in the RLP process and to reduce the paste waste by 10% through implementation of recycled paste. The project was implemented using the DMAIC (Define, Measure, Analyze, Improve, Control) approach of Six Sigma tools such as Fishbone Diagram, Fault Tree Analysis (FTA) and SMART. The study involved data collection on paste consumption, testing the feasibility of recycled paste, and applying the optimized method in real production. Pilot testing is carried out to investigate the viability of recycling and reusing leftover paste to support process optimization initiatives. Before the implementation of reusing recycled paste, the paste waste was 667.32g. This excess paste will be further disposed of. After implementing paste reuse, results showed a 56% reduction in paste waste, exceeding the original 10% goal. This not only helped reduce costs but also supported a more sustainable manufacturing process. This project supports environmentally conscious manufacturing while also supporting the company's cost-cutting objectives by addressing waste through recycling and process improvement strategies.

Keywords: resistive layer printing (rlp), recycled Paste, paste waste reduction, sustainable manufacturing, cost reduction

1.0 INTRODUCTION

The project titled *"Optimizing Paste Waste at P10 Printing Process by Using Recycled Paste"* was carried out at Company XY, a company specializing in the manufacturing of electronic components through the Resistive Layer Printing (RLP) process. One of the key issues identified was the excessive waste of overcoat paste 1025 during the P10 printing process. This waste not only increased production costs but also reduced material efficiency. The paste, typically discarded after each print lot, was considered unusable due to its exposure to air and hardening properties. The aim of this study was to explore sustainable and cost-effective strategies to minimize paste waste without compromising product quality. Specifically, the project focused on identifying a comprehensive waste reduction strategy and evaluating the effectiveness of using recycled paste in the manufacturing process. As highlighted by Sauerwein et al. (2020), implementing reuse strategies in manufacturing supports circular economy principles and leads to greater material efficiency and environmental sustainability.

1.1 Problem Statement

In the current P10 printing process, a substantial amount of overcoat paste 1025 is wasted. This is primarily due to the manual application of paste, absence of standard procedures for reuse, and environmental conditions that lead to the paste hardening quickly. Operators typically discard leftover paste after completing a batch, believing it is no longer suitable for reuse. The lack of proper paste handling and recycling protocols exacerbates the issue, leading to high material costs and operational inefficiencies. Consequently, there was a clear need for a structured waste reduction approach that could recover and reuse leftover paste while ensuring that product quality remained intact.

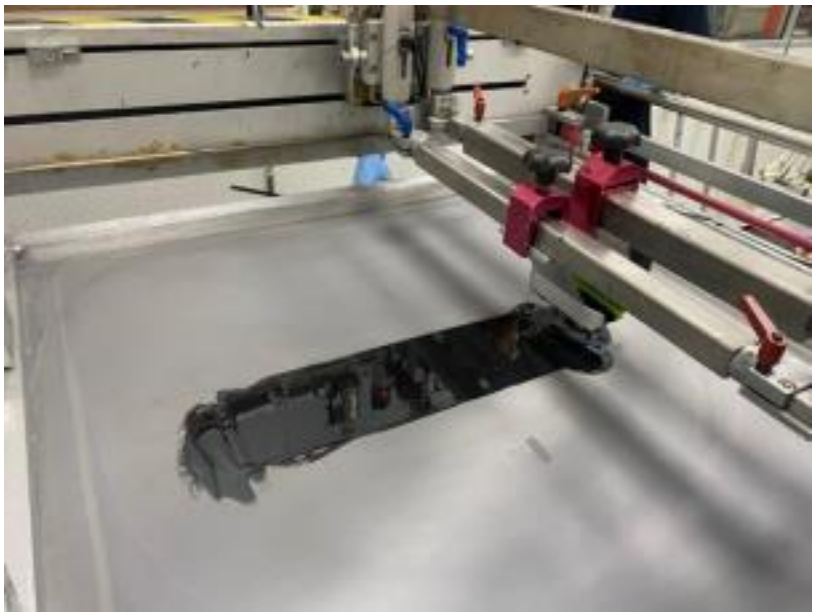


Figure 1: Remaining excess paste on the screen to be discarded

1.2 Research Objective

- To identify solutions for a comprehensive paste waste reduction strategy in the Resistive Layer Printing (RLP) process.
- To reduce the paste waste by 10% through implementation of recycled paste.

2.0 METHODOLOGY

2.1 DMAIC Methodology

The project adopted the DMAIC (Define, Measure, Improve, Analyze, Control) methodology from Lean Six Sigma to structure the research and improvement efforts. The research project at Company X aims to reduce paste waste in the Resistive Layer Printing (RLP) process.

A. Define:

The project clearly identifies the main issue of high paste waste and material costs in the P10 printing process. The objective is to reduce the waste of overcoat paste 1025 without compromising product quality. A detailed project plan is developed, outlining the goals, scope, and expected outcomes to guide the efforts throughout the process.

B. **Measure:**
The Measure phase follows, where data is gathered to gain a comprehensive understanding of the current situation. This includes collecting information on paste usage, waste quantities, and defect rates. The data collected establishes a performance baseline, which is crucial for evaluating the effectiveness of the proposed improvements.

C. Analyze:
The Measure phase included observations, interviews, and quantitative tracking of paste usage. During this phase, the root causes of paste waste are identified using analytical tools such as the Fishbone (Ishikawa) diagram and the Fault Tree Analysis (FTA) to reveal several causes of waste, including inconsistent manual paste application, lack of operator training, and environmental conditions that accelerated paste hardening (Hassan et al., 2013).

D. Improve:
In this improvement phase, recycled paste is introduced in controlled trial runs. To address the problem, the Improve phase introduced a recycling method. Leftover paste was collected, stored in a freezer, defrosted for six hours, and blended thoroughly before reuse. This method was guided by King et al. (2021), who demonstrated that on-site recycling of electronic pastes can reduce environmental impact by up to 92% and cut associated costs by 40%. The blending process helped restore the paste's consistency and ensured it remained suitable for application. Research by White et al. (2021) further supported that recycled materials can maintain quality and performance when processed under controlled conditions.

E. Control:
In the control phase, new Standard Operating Procedures (SOPs) or One Point Lesson (OPL) were established in RLP process. Operators were trained in the new handling and reuse of recycled paste. This was supported by findings from Taylor and Clark (2022), who emphasized the importance of structured training and standardization in maintaining long-term material efficiency and process control.

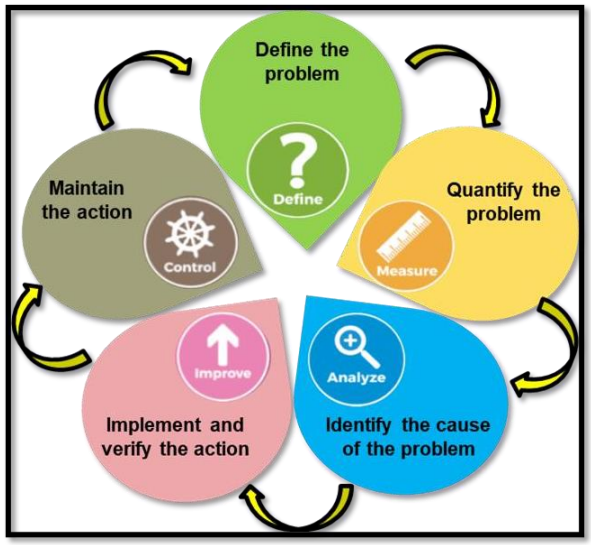


Figure 2: DMAIC Methodology

2.2 Target Setting (SMART)

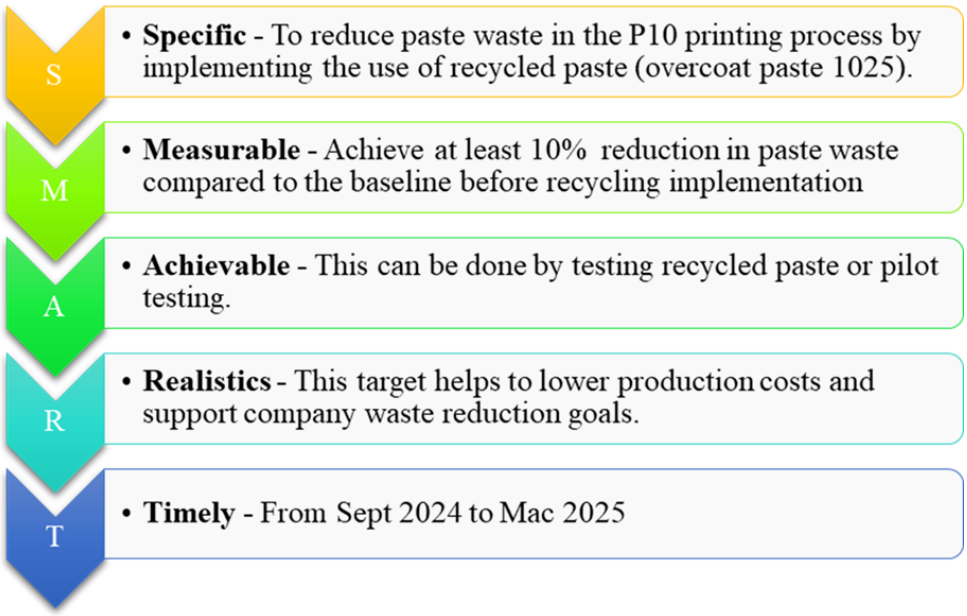


Figure 3: SMART Target Setting

Based on figure 3 above, this project uses the SMART method to set a clear and realistic goal. SMART stands for Specific, Measurable, Achievable, Relevant, and Time-bound. It helps guide the project, track progress, and reach the goal on time. The goal of reducing waste and saving costs is realistic because it can be done by running trials and using the right recycling method. By using SMART, the project has a clear target that helps reduce waste and improve efficiency in the P10 printing process. Since the goal is specific and measurable, it is easier to check the progress and compare the results before and after the changes. Lean tools were implemented to analyse workflow and eliminate non-value-adding activities findings showed a 12% cost reduction in material usage after process optimization. (Abdullah & Fadzil, 2023)

3.0 RESULTS AND DISCUSSION

3.1 Evaluation Results Using Recycled Paste

This section presents the evaluation of the results collected before and after the implementation of the recycled paste method in the P10 printing process. The purpose of this evaluation is to measure the effectiveness of the new method in reducing waste and improving cost efficiency. By comparing the data collected, such as paste usage, waste amount, and product quality, the success of the project can be clearly identified. This evaluation also helps determine whether the project goals were achieved and if the recycled paste method can be applied consistently in future production processes.

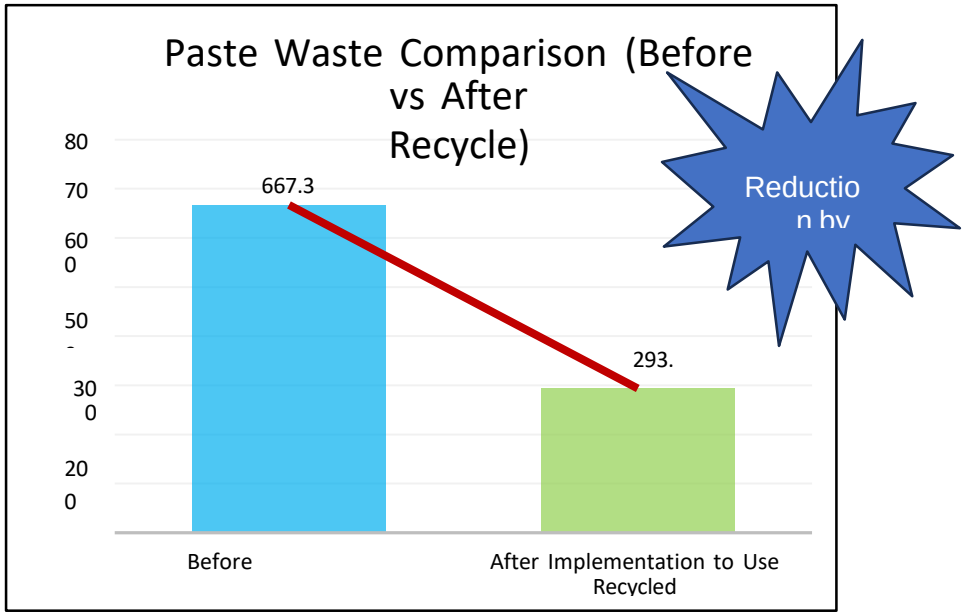
Table 1: Comparison before and after implementation of recycled paste

	Before Implementation to Use Recycled Paste				After Implementation to Use Recycled Paste			
	Weight Paste Used Before Printing	Weight Paste Used for Printing (g)	Weight Remaining Paste After Printing (g)	Total Finish Lot	Weight Remaining Paste After Printing (g)	Weight Paste Used for Printing (g)	Weight Remaining Paste After Printing (g)	Total Finish Lot
	125.7	41.9	83.8	35	83.8	52.00	31.8	44
	125.6	39.9	85.7	35	85.7	53.40	32.3	45
	125.2	25.4	99.8	20	99.8	69.60	30.2	58
	125.22	37.45	87.77	30	87.77	54.27	33.5	46
	125.25	71.21	54.04	51	54.04	22.34	31.7	19
	125.45	54.76	70.69	25	70.69	36.19	34.5	30
	125.3	55.65	69.65	30	69.65	36.25	33.4	30
	125.3	68.93	56.37	42	56.37	23.67	32.7	20
	125.3	65.8	59.5	36	59.5	25.90	33.6	22
Total	1128.32	461.00	667.32	304	667.32	373.62	293.70	314
Average	125.37	51.22	74.15	34	74.15	41.51	33	35
	Total Paste Used Before Printing			1128.32g	Total Paste Used Before Printing			667.32g
	Paste Used for Printing			461g	Paste Used for Printing			373.62g
	Paste Waste			667.32g	Paste Waste			293.7
	Total Output (Finish Lot)			304 lot	Total Output (Finish Lot)			314 lot
	Total Finish Strip			12,160	Total Finish Strip			12,560
	Total Output (In Pcs)			1,580,800	Total Output (In Pcs)			1,632,800

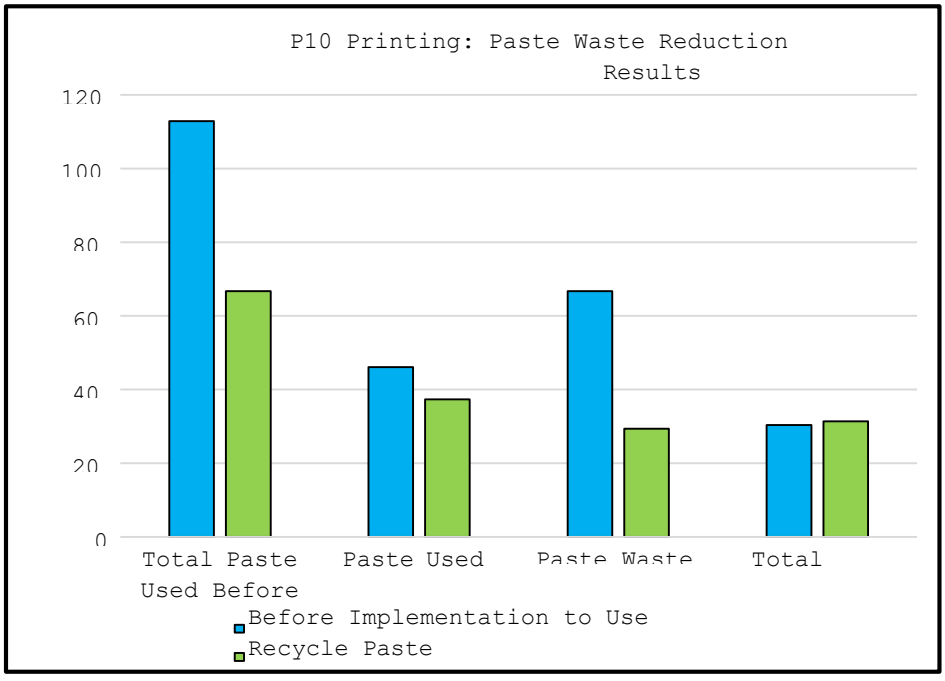
Based on table 1, the findings of this project showed a significant improvement in reducing paste waste through the implementation of a recycled paste strategy. The implementation of the recycled paste method in the P10 printing process showed a clear reduction in paste waste without affecting product quality. Prior to the improvement, the average paste usage per lot was 51.22 grams, with a total usage of 1128.32 grams and a paste waste of 667.32 grams. After applying the new method, the average paste usage per lot decreased to 41.51 grams, total usage dropped to 607.14 grams, and paste waste was reduced to 293.70 grams.

Table 2: Results of evaluation (Before and after implementation to use recycle paste)

BEFORE IMPLEMENTATION		**TER IMPLEMENTATION TO USE RECYCLED PASTE**	
Total Paste Used Before Printing	1128.32g	Total Paste Used Before Printing	667.32g
Paste Used for Printing	461g	Paste Used for Printing	373.62g
Paste Waste	667.32g	Paste Waste	293.7
Total Output (Finish Lot)	304 lot	Total Output (Finish Lot)	314 lot
Total Finish Strip	12,160	Total Finish Strip	12,560
Total Output (In Pcs)	**1,580,800**	**Total Output (In Pcs)**	**1,632,800**



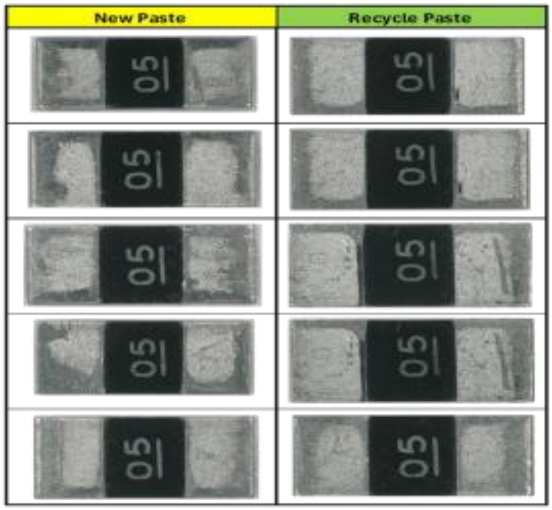
Based on figure 4, the graph shows that paste waste was reduced after using recycled paste in the P10 printing process. The red line in the graph shows this big decrease. Before the change, the total amount of waste was 667.32 grams. After implementing recycled paste, the waste dropped to 293.7 grams. This means that the new method worked well and helped to reduce waste. Process optimization, particularly in parameter settings such as paste thickness, squeegee pressure and print speed, significantly minimized paste wastage (Kumari et al.,2024) It also supports the goal of the project, which is to save costs and use paste more efficiently.



The bar chart in figure 5 above shows a clear improvement after using recycled paste in the P10 printing process. Total paste usage dropped from 1128.32g to 667.32g, and paste waste was reduced by 56%, far better than the 10% target. Paste used for printing also decreased,

showing better efficiency. The output increased from 304 to 314 lots, proving that product quality was not affected. Overall, the project successfully cut costs, reduced waste, and made the process more efficient and eco-friendlier.

Table 3: Comparison of successful products (Good Product) using recycled paste between new paste and recycled paste



In table 3, visual inspections of products made with recycled paste showed no defects such as peeling, pinholes, or poor adhesion. The laser marking process also produced clear and accurate results which no defects such as marking NG, marking incomplete and no marking were detected. This proves that the use of recycled paste does not impact the performance of the laser marking process, and the final product continues to meet the appearance specifications for good chips.

Table 4: Results analysis from implementation of recycled paste

Metric	Before Implementation to Reused Recycle Paste	After Implementation to Reused Recycle Paste	Result
Total Paste Used	1128.32g	667.32g	Reduced by 461g
Paste Used for Printing	461g	373.62g	Reduced
Paste Waste	667.32g	293.70g	Reduced by 373.62 (56%)
Total Output (Finish Lot)	304 Lot	314 Lot	Increased by 10 Lot
10% Reduction Target		600.59g	Met and Exceeded

Based on the table 4 above, it shows that implementation of the recycled paste strategy resulted in a 56% reduction in paste waste, far exceeding the original target of 10%.

3.2 Discussion

This project was carried out to find out if recycling overcoat paste 1025 could help reduce paste waste during the P10 printing process at Company XY. The result showed that using a recycled paste method by freezing, defrosting, and blending leftover paste successfully reduced paste waste by 56%. This is much higher than the original goal of reducing waste by just 10%. The products made with recycled paste passed all quality checks, including appearance and laser marking. This proves that recycled paste does not affect product performance when the process is followed correctly. This project is important because it helps the company save money and supports environmentally friendly practices. Using recycled paste means less material is thrown away and fewer new materials are needed. While the results were successful, there are still some things to consider. This study was done in a controlled production environment. More testing in different situations or over longer periods may help confirm the results further. Future work could also investigate how long recycled paste can last and whether the same method works with other types of paste. In conclusion, this study proved that using recycled paste is a good way to reduce waste and keep quality high. It offers a simple and low-cost solution that other companies can follow to improve both efficiency and sustainability.

4.0 CONCLUSION

The project at Company XY successfully met its two-core objective. The project took place at Company XY, where a lot of overcoat paste 1025 was being thrown away after each print job. The study found that a significant amount of paste was being wasted after each printing cycle, mainly due to lack of standard procedures for reusing back paste. To solve this, the team applied the DMAIC (Define, Measure, Analyze, Improve, Control) method to understand the problem, identify the causes, and implement a solution. The solution involved collecting leftover paste, freezing it, defrosting it for six hours, and blending it thoroughly before reusing it. After this method was introduced, paste waste was reduced by 56%, which greatly exceeded by reusing materials that would otherwise be thrown away, the company can reduce its impact on the environment and promote sustainable manufacturing practices. The initial target of just 10%. This showed that recycled paste could be reused effectively and safely in production. Tests and product quality checks confirmed that the recycled paste performed just as well as the new paste. There were no defects or problems found in the final products. To support this improvement in the long term, new standard operating procedures were created, and workers were trained in how to handle and reuse paste correctly. This helped ensure that the new process could be followed consistently in daily operations. In conclusion, the project clearly showed that using recycled paste is a practical, effective, and sustainable solution for reducing waste in the P10 printing process

ACKNOWLEDGMENT

First of all, I would like to sincerely thank Company XY for giving me the chance to do my final year project titled *"Optimizing Paste Waste at P10 Printing Process by Using Recycled Paste."* I am very grateful to the Production Department for their support, the resources provided, and for welcoming me into their working environment during this project. A special thank you goes to my industrial supervisor, En. Mohd Helmi Rashidi bin Harunarashid, for his constant encouragement, practical advice, and for sharing his knowledge, which really helped me carry out and complete the project. I am also very thankful to my academic

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Optimizing Storage Space Utilization through Lean Six Sigma in Warehouse Operation

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ABSTRACT

This study investigates the optimization of warehouse storage space using Lean Six Sigma methodology, focusing on the application of cantilever racks for long and heavy materials such as metal rods and steel bars. The primary objective is to resolve the issue of underutilized storage by identifying its root causes and implementing a more efficient storage system. A stress test was conducted to determine the maximum load capacity of the existing cantilever racks, ensuring safety in the proposed layout redesign. The research employs a structured Lean Six Sigma approach to eliminate waste, improve accessibility, and enhance warehouse performance. Key findings show a significant improvement in storage density, inventory organization, and overall operational efficiency. The study concludes by recommending continued application of Lean Six Sigma tools and regular load assessments to sustain long term storage optimization.

Keywords: lean six sigma, storage optimization, warehouse efficiency, cantilever racks, inventory management.

1.0 INTRODUCTION

Efficient storage management is crucial in supply chain operations, especially in manufacturing industries where optimizing space utilization can directly impact productivity and operational efficiency. At Benchmark Electronics' warehouse in Bayan Lepas, Penang, a significant challenge has been identified in the form of underutilized storage space. This issue is particularly prevalent in the areas where long and heavy items such as metal rods, 2/1 steel bars, and similar materials are stored using cantilever racks. Despite these racks being designed to handle large and heavy inventory, their potential is not being fully realized, resulting in wasted space and inefficiency in the warehouse.

This project aims to resolve these inefficiencies by applying Lean Six Sigma principles to optimize the storage layout and maximize warehouse capacity. Through a comprehensive analysis, the study will identify the root causes of underutilized space and will propose a systematic solution to redesign the storage layout effectively. One key aspect of the study will be conducting a stress test on the current cantilever racks to assess their maximum load-bearing capacity. The findings from this test will provide critical data necessary for adjusting loading practices and ensuring that the racks are used to their full potential without compromising their structural integrity.

In addition to space optimization, the project will focus on improving the accessibility of stored items, which is crucial for reducing retrieval times and minimizing delays. Inefficient storage practices not only increase operational costs but also create bottlenecks that slow down production workflows. By reorganizing the warehouse layout and applying Lean Six Sigma tools, this project aims to reduce waste, improve inventory organization, and ultimately increase warehouse productivity. The expected outcomes include enhanced storage density, more efficient use of space, and a streamlined inventory system that supports faster retrieval and better operational flow, ultimately contributing to a more efficient supply chain.

1.1 Problem Statement

The warehouse at Benchmark Precision Technology is facing significant inefficiencies due to the underutilization of its cantilever racks, which are specifically designed for storing long and heavy items such as metal rods, 2/1 steel bars, and other similar materials. These cantilever racks, which provide the optimal solution for storing such materials, are not being used to their full potential. The items are often stored haphazardly, without a clear and standardized system, leading to wasted vertical and horizontal space. This underutilization of the racks results in inefficient storage practices, increasing operational costs and complicating inventory management.

The lack of a well-defined storage strategy for long and heavy items is a major contributor to these inefficiencies. The cantilever racks, which have the structural capacity to accommodate large items, are not optimized for their intended purpose. As a result, significant portions of the available storage space remain unused, leading to reduced storage density, longer retrieval times, and slower overall warehouse operations.

Preliminary observations suggest that the primary causes of these issues are the absence of standardized storage processes and outdated infrastructure, which fails to maximize the capacity of the cantilever racks. This lack of systematization makes it challenging to effectively utilize the space available, contributing to the overall inefficiency in warehouse operations.

To address these challenges, a data-driven approach is essential. By assessing the current storage layout and identifying inefficiencies, this project aims to optimize the use of cantilever racks, ensuring they are used to their full potential. The goal is to redesign the storage system in a way that maximizes vertical and horizontal space utilization, streamlines inventory management, and improves operational efficiency at Benchmark Precision Technology.

1.2 Objective

To identify the causes of underutilized storage space in the warehouse.

1.3 Scope

This study focuses exclusively on the optimization of cantilever rack utilization at Benchmark Precision Technology's warehouse. The analysis is centred on how long and heavy items such as metal rods and 2/1 steel bars are stored using cantilever racks. The project involves examining the current storage layout to identify causes of underutilized space and proposes improvements specifically aimed at maximizing vertical and horizontal space efficiency.Other aspects such as load-bearing assessments and procedural implementations are beyond the scope of this study and were not included in the actual project execution.

1.4 Significance of the Study

This study is specifically focused on optimizing the utilization of cantilever racks within the warehouse operations of Benchmark Precision Technology. The primary emphasis is on evaluating the storage practices used for long and heavy items particularly metal rods and 2/1 steel bars which present unique challenges due to their irregular sizes and non-stackable nature. The analysis is confined to assessing how these materials are currently stored and how the existing cantilever racking system contributes to or hinders efficient space utilization.

The core objective of the study is to identify the causes of underutilized space within these racks by closely examining the current layout and operational practices. Based on this

assessment, the study aims to propose targeted improvements that can enhance both vertical and horizontal space usage, leading to greater storage density and operational efficiency.

It is important to note that the scope of this research is deliberately limited to diagnostic and analytical activities. Components such as stress testing the structural load capacity of the racking system, implementing new shelving systems, or developing standardized storage procedures were identified as valuable future considerations but were excluded from the current project's execution. As such, the study offers a foundational analysis that informs future development, while remaining focused on the present state of cantilever rack usage within the defined operational environment.

2.0 METHODOLOGY

2.1 Participants

This study involved a total of eight participants from Benchmark Precision Technology's warehouse operations team. The participants included one warehouse manager, two supervisors, and five general warehouse staff. These individuals were directly involved in providing insights on the current storage setup and operational challenges related to cantilever rack usage. Their experience and observations were essential in identifying inefficiencies and validating the findings of the study.

2.2 Instruments

This study employed both qualitative and quantitative instruments to support a case study approach. Data collection involved direct field observation, manual measurements of storage space, and participant input from warehouse personnel. Autodesk Inventor was used to digitally recreate the existing cantilever racking system, allowing for a more precise analysis of spatial usage and inefficiencies. The digital model served as a visual REFERENCES to assess current layout limitations and identify opportunities for space optimization.

2.3 Research Procedures

The research process commenced with a systematic observation of the existing warehouse setup, with specific attention given to the storage of long and heavy items such as metal rods and 2/1 steel bars, which were housed on cantilever racks. This initial phase aimed to identify visible inefficiencies and gather contextual understanding of how space was currently being utilized. Observations were carefully documented to support later analysis.

Following this, semi-structured interviews were conducted with key personnel within the warehouse, including the warehouse manager, two supervisors, and five operational staff members. These interviews provided valuable qualitative insights into daily storage practices, challenges faced in managing long items, and limitations associated with the current racking system. The input from these stakeholders was instrumental in validating field observations and framing the scope of the investigation.

Once the observational and qualitative data were collected, precise measurements of the cantilever racks and the occupied material space were taken. These measurements were then used to digitally reconstruct the racking system using Autodesk Inventor**,** a professional-grade 3D design software. The use of digital modelling enabled detailed visualization of the existing layout, allowing for a more accurate and objective assessment of space utilization.

Importantly, the study did not proceed to test or compare alternative configurations. Instead, the analysis was intentionally focused on diagnosing inefficiencies within the current setup as it existed in real operational conditions. This approach ensured that findings and CONCLUSION were grounded in actual warehouse practices, thereby enhancing the practical relevance and reliability of the study.

3.0 RESULT AND DISCUSSION

The analysis revealed that only 14.44% of the available cantilever rack space was effectively utilized, indicating a significant level of underutilization within the existing warehouse setup at Benchmark Precision Technology. This low utilization rate reflects a critical inefficiency in the storage system, particularly in the areas designated for long and heavy materials such as metal rods and 2/1 steel bars. Due to their irregular sizes and non-stackable nature, these items cannot be safely layered vertically, resulting in substantial unused vertical space.

A key contributor to this inefficiency is the design of the cantilever racks themselves. The current racking system consists of a single, open section without any form of structural segmentation or dividers. This absence of internal separation limits the ability to organize materials systematically, making it difficult to optimize space usage. Items are often placed in a disorganized manner, which not only reduces storage density but also complicates access and retrieval.

The findings of this study directly support the core objective to identify the root causes of underutilized storage space in the warehouse. Through detailed observation and measurement, the study confirms that the primary factor leading to inefficiency is the lack of structural segmentation within the racking system. Without mechanisms to divide or categorize stored materials, large portions of both vertical and horizontal space remain unused. By isolating this specific issue, the study provides a clear and actionable insight into the core limitations of the current storage system, laying the foundation for future improvement initiatives aimed at enhancing warehouse performance.

3.1 Table and Figure

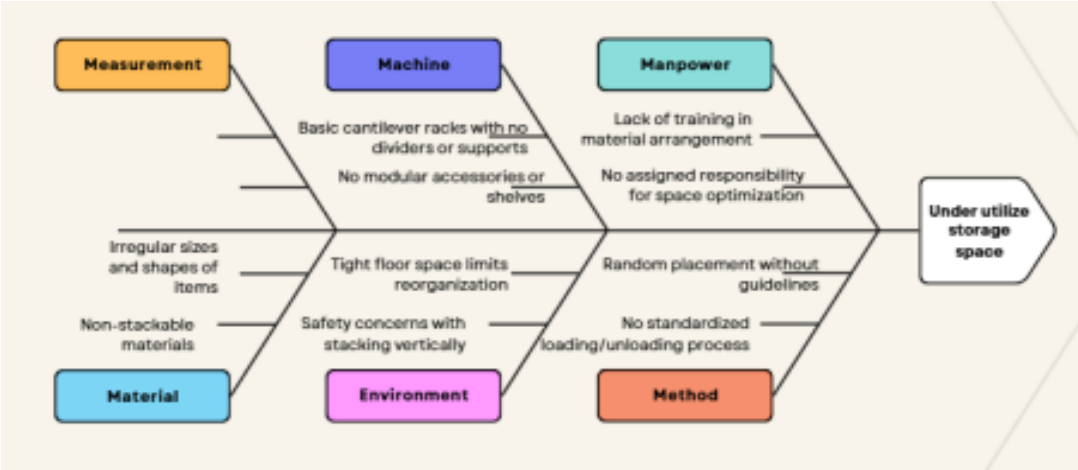

Figure 1: Fishbone Diagram

Under the *Material* category, the irregular sizes and shapes of long items such as metal rods, along with their non-stackable nature, present major challenges in optimizing space. In the

Machine category, the cantilever racks were found to lack dividers, supports, and modular features such as shelves, making it difficult to separate or layer materials effectively. For *Manpower*, the issues stem from a lack of training in proper material arrangement and the absence of assigned responsibility for maintaining organized storage. The *Method* category highlights inconsistent practices, where materials are placed randomly without clear guidelines, and no standardized procedures exist for loading and unloading. *Environmental* factors such as limited floor space and safety concerns about vertical stacking further restrict storage efficiency. Finally, the *Measurement* category suggests that the absence of accurate and consistent space usage monitoring tools may limit ongoing improvement efforts. Altogether, the diagram underscores that while the root issue is structural, it is deeply interconnected with human, procedural, and environmental factors all of which contribute to the current inefficiencies observed in the warehouse.

$$\text{Space Utilization Rate} = \frac{\text{Total Space Used}}{\text{Total Available Space}} \times 100$$

$$\text{Space Utilization Rate} = \frac{(1.32 \times 4.13 \times 0.05)\text{m}}{(1.37 \times 4.13 \times 0.33)\text{m}} \times 100$$

$$= \frac{0.27\text{m}^3}{1.87\text{m}^3} \times 100$$

$$= 14.44\ \%\ \text{space utilized}$$

Figure 2: Space Utilization Rate Calculation

To quantify the level of inefficiency in the warehouse storage system, the space utilization rate was calculated using the formula:
Space Utilization Rate = (Total Space Used ÷ Total Available Space) × 100.

Based on measurements taken from the existing cantilever rack, the total volume occupied by stored materials was found to be 0.27 cubic meters (1.32 m × 4.13 m × 0.05 m), while the total available space within the racking unit was 1.87 cubic meters (1.37 m × 4.13 m × 0.33 m). Applying the formula, the resulting utilization rate was calculated to be 14.44%, indicating that a significant 85.56% of the rack space remains unused. This finding strongly supports the conclusion that the storage system is highly inefficient, mainly due to the inability to stack materials and the absence of structural segmentation within the cantilever racks.

4.0 CONCLUSION

This study confirmed that for warehouses handling long, heavy, and irregularly shaped items, such as metal rods and 2/1 steel bars, the presence of structural segmentation within cantilever racks is a critical factor for maximizing space utilization. The analysis conducted at Benchmark Precision Technology revealed that the current cantilever racks, which consist of a single open section with no dividers or supports, contribute directly to the underutilization of available storage space. Because the stored materials vary in length and cannot be stacked, this lack of compartmentalization results in inefficient use of both vertical and horizontal space.

The calculated space utilization rate of only 14.44% is a strong indicator of the system's inefficiency. The inability to divide or properly arrange items has led to excessive empty space between loads and a disorganized layout, complicating inventory handling, increasing retrieval times, and contributing to workflow delays. This inefficiency not only affects daily operations but also leads to higher operational costs, lower productivity, and safety concerns due to unstable loading practices.

By identifying structural segmentation as the main root cause, this study offers warehouse managers a targeted area for improvement. The insights gained from this analysis can guide practical upgrades to the current storage infrastructure, such as reengineering the rack layout to introduce adjustable dividers, modular shelves, or tiered supports. These additions would allow materials to be organized more systematically based on size, type, or frequency of use, reducing clutter and improving accessibility.

As a key recommendation, it is proposed that the warehouse develop and implement a custom shelving system that integrates directly with the existing cantilever racks. This solution should be designed to support the safe handling of irregular materials while enabling full use of the rack's vertical capacity. With proper structural segmentation, the warehouse can expect to achieve significantly higher space utilization, streamlined inventory management, and overall improvements in storage density, safety, and operational efficiency. Moreover, this approach can serve as a REFERENCES model for other facilities facing similar challenges in space management.

APPENDIX

Figure 3: Cantilever Racking

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Optimizing Warehouse Layout And Inventory Classification To Reduce Picking Time For Raw Materials And Finished Goods.

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ABSTRACT

This project aims to identify inefficiencies and bottlenecks in the current warehouse layout and inventory tracking system, with a particular focus on long picking times and inaccurate cycle counts. The project will reorganize the warehouse layout and implement item classification based on movement frequency using FSN (Fast, Slow, Non-moving) analysis. Frequently accessed items will be positioned for easy access, while less demanded stock will be strategically stored to minimize unnecessary handling. Unique location identifiers will be introduced for all storage racks and integrated with the ZOHO inventory system to enhance real-time tracking and inventory accuracy. A mixed-methods approach combining historical data analysis, time-motion studies and simulation modelling will be used to understand current inefficiencies. 3D modeling tools like Coohom will be used to create a model warehouse to identify bottlenecks, and refine the proposed layout. The project targets a 10– 15% reduction in average picking times for both raw materials and finished goods, 10% increase in overall storage efficiency. These improvements aim to streamline operations, improve inventory control, and support scalable growth.

Keywords: warehouse management, FSN analysis, picking time, inventory tracking system, simulation modeling

1.0 INTRODUCTION

1.1 Objectives and literature Review

The primary objective of this project is to optimizing the current warehouse layout to reduce picking time and increase space utilization in warehouse, The primary objective of this project is to optimize storage space utilization in the warehouse of by reorganizing and strategically positioning items based on their movement frequency. This optimization aims to increase overall storage efficiency and space utilization by 10%, addressing inefficiencies caused by unplanned storage, blocked access ways, and cluttered floor space that currently hinder warehouse productivity. Inventory classification into fast-moving, slow-moving, and non-moving categories using FSN analysis is employed to facilitate targeted allocation of stock, enabling quick retrieval of frequently accessed items while relegating slow- and non- moving items to less accessible storage racks. This approach not only aims to improve space utilization but also reduce picking time and operational delays, thereby enhancing workflow efficiency.

FSN (Fast, Slow, Non-moving) analysis is a widely recognized inventory classification technique that categorizes items based on turnover rates or usage frequency, enabling better inventory control and storage allocation (Amudha & Aadhithyan, 2024). By applying FSN principles, this project seeks to systematically organize the warehouse layout, minimize unnecessary item handling, and streamline the picking process. Integration with the ZOHO inventory system further enhances cycle counting accuracy and stock traceability. The study is significant in its potential to improve warehouse performance metrics and support scalable growth in the competitive automotive parts manufacturing sector.

Warehouse management optimization is vital for efficient supply chains, especially in industries needing fast order fulfilment and accurate inventory control. Bartholdi and Hackman (2019) highlight that strategic warehouse layouts, with slotting based on item movement frequency, reduce picker travel distances and improve throughput by placing high-turnover items in accessible locations. Underutilized space can be addressed through dynamic slotting and shared storage**.** FSN classification effectively prioritizes fast-moving items while optimizing slow- and non-moving stock placement (Mitra, Reddy, & Prince, 2015). Amudha and Aadhithyan (2024) show FSN improves cycle count accuracy and reduces picking times, also enhancing integration with inventory systems to reduce errors.

Simulation techniques like Discrete-Event Simulation (Preedawat et al., 2022) help optimize layouts without disrupting operations, cutting picking times and improving space use. Pawlewski (2015) confirms simulation-based slotting and routing reduce travel distances by over 15%, boosting productivity. Layouts such as U-shaped and cluster storage aid project-specific segregation and space efficiency, with FSN placement maximizing picking speed (Rushton, Croucher, & Baker, 2014). Regular FSN reassessment ensures adaptation to demand changes (Sharda & Gorana, 2021).

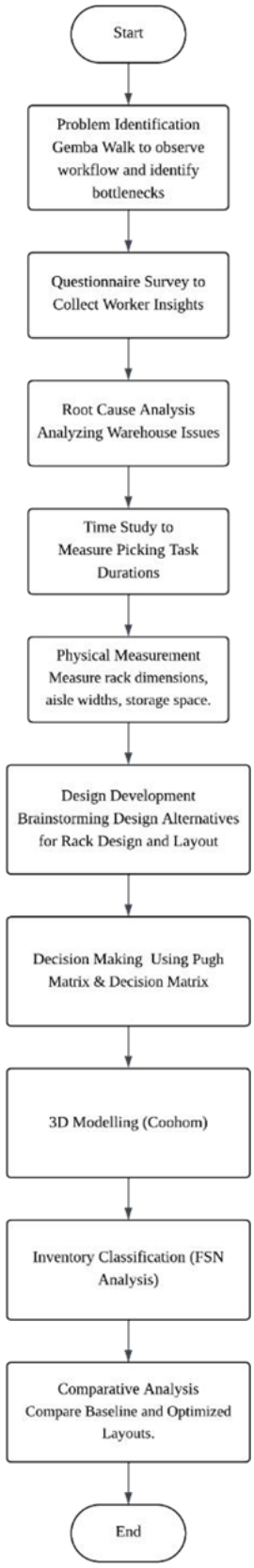
Integrating FSN classification, optimized layouts, and simulation offers a comprehensive solution to reduce picking times, improve inventory accuracy, and enhance space utilization, supporting lean manufacturing and better customer service.

1.0 Problem Statement

In the competitive automotive manufacturing sector, warehouse operations play a critical role in maintaining an efficient supply chain. an automotive parts manufacturer, is currently facing significant inefficiencies in its warehouse management, particularly in the areas of prolonged picking times and space utilization. The existing warehouse layout and inventory classification system fail to address these issues effectively, leading to underutilized space, excessive picking times, and challenges in maintaining accurate inventory records.

By utilizing FSN (Fast-moving, Slow-moving, Non-moving) analysis to improve inventory classification and optimize warehouse layout, this study seeks to address these issues. It is anticipated that picking times would decrease and warehouse space will be used more efficiently by rearranging storage locations and sorting items according to their movement rates. Enhancing inventory management procedures can also assist guarantee precise stock levels, which will lessen operational delays and stock inconsistencies.

2.0 METHODOLOGY



Flow Chart above shows the Process Flow of this project.

The flowchart outlines a structured methodology for optimizing warehouse operations, beginning with problem identification through Gemba walks to observe workflow inefficiencies. This is followed by a questionnaire survey to gather frontline worker insights. A root cause analysis is then conducted to identify underlying warehouse issues, complemented by a time study to measure picking durations and physical measurements to assess spatial dimensions such as rack sizes and aisle widths. Based on these findings, the design phase involves brainstorming alternatives for rack and layout improvements. These alternatives are evaluated using the Pugh and Decision Matrix methods to select the most effective solutions. The chosen designs are modelled in 3D using Coohom to visualize improvements. Inventory is then classified using FSN (Fast, Slow, Non-moving) analysis to inform strategic item placement. Finally, a comparative analysis is performed to assess improvements between the original and optimized layouts, completing the cycle of data-driven warehouse enhancement.

2.0 RESULTS AND DISCUSSION

2.1 Questionnaire Analysis

The questionnaire conducted among warehouse workers provided valuable insights into the current operational challenges within the warehouse. Responses highlighted several critical issues affecting workflow efficiency, space utilization, and safety. Workers identified problems such as difficulty locating items quickly, inadequate aisle widths, congestion due to poor space management, and insufficient segregation of products. There was also widespread dissatisfaction with the placement of frequently accessed items and concerns regarding safety risks linked to limited visibility and sharp turns in the layout. Additionally, storage capacity constraints were a recurring theme, indicating the need for improved racking solutions. This collective feedback underscores the urgency of implementing targeted layout optimizations and strategic inventory reorganization to enhance overall warehouse performance.

Table 1: Analysis of the Questionnaire.

No.	Question Topic	Key Findings
1	Worker tenure in warehouse	40% worked 2–5 years, 40% >5 years, 20% for 6 months–2 years. None below 6 months.
2	Daily hours spent on physical movement	40% >6 hours, 40% between 4–6 hours, 20% between 2–4 hours. None below 2 hours.
3	Ease of locating items in current layout	40% strongly disagreed, 40% disagreed, 20% neutral. None agreed.
4	Sufficiency of aisle width for equipment movement	20% strongly disagreed, 40% disagreed, 40% neutral. None agreed.
5	Experience of congestion and storage arrangement	100% experienced congestion and reshuffling. 80% noted items on the floor.
6	Segregation of product types in layout	80% disagreed, 20% strongly disagreed. None agreed.

7	Convenience of frequently accessed items placement	60% disagreed, 40% strongly disagreed. None agreed.
8	Efficiency of current warehouse layout	20% rated very inefficient, 40% somewhat inefficient, 40% neutral. None rated efficient.
9	Visibility and blind spots for equipment operators	20% strongly disagreed, 40% disagreed, 40% neutral. None agreed.
10	Sufficiency of current racking levels	80% disagreed, 20% neutral. None agreed.

3.2 Root Cause Analysis

The Ishikawa diagram identified five primary causes of warehouse inefficiency: Inventory Management, Equipment Movement and Safety, Layout, Space Utilization, and Racking System. These factors collectively contribute to delays, congestion, and safety risks, emphasizing the need for a comprehensive approach to warehouse optimization.

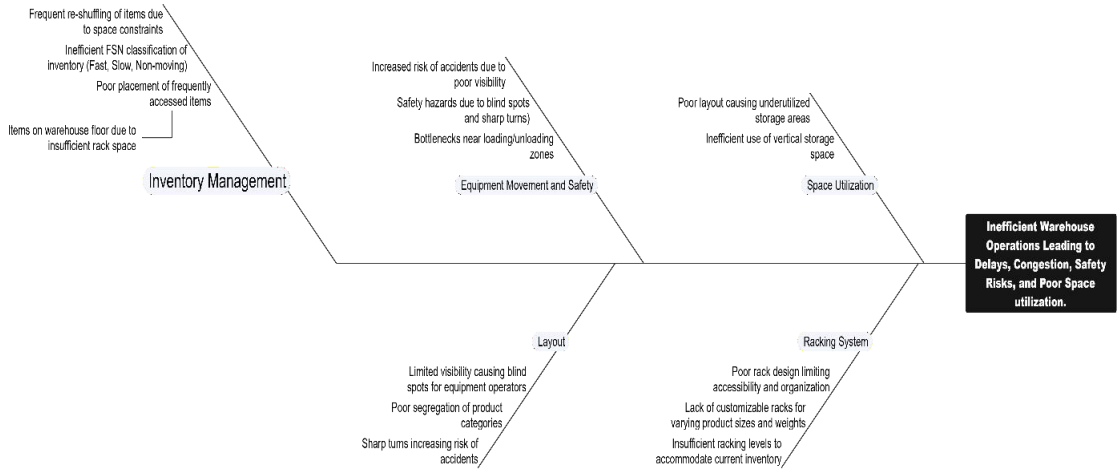


Figure 1: Ishikawa Diagram used.

3.3 Racking Design Evaluation

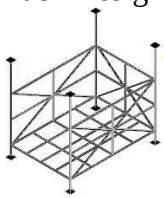
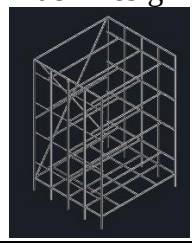
PVC and PUR rolls require significant storage space due to their dimensions. Current storage consumes 28.75 m², limiting available floor space. Two rack designs were proposed and evaluated using the Pugh Matrix.

Table 2 : Current Total SQM for PVC and PUR storage.

Description	Length (m)	Width (m)	Number of Rolls	Total Area (^{2})
PVC and PUR rolls Storage	11.5	2.5	24 rolls	28.75

Figure 2: Current storage of PVC and PUR rolls.

Table 3: Pugh Matrix

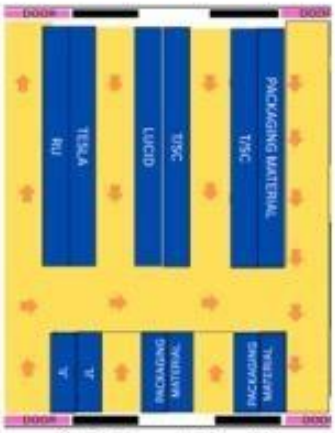
Criteria	Design		
	Datum	Rack Design 1 	Rack Design 2 
Stickability	0	+1	-1
Sqm Occupied	0	+1	-1
Amount of Rolls Can Fit	0	+1	+1
Simplicity of Design	0	+1	-1
Ease of Retrieving & Storing	0	+1	-1
Score	-	.+4	-2
Rank	-	1st	2nd

Rack Design 1 was chosen as the preferred option based on the Pugh matrix evaluation because it achieved the highest overall score of +4, outperforming Rack Design 2, which scored -2. This design excels in several key areas compared to both the datum and Rack Design 2. It supports secure stacking, enhancing vertical space utilization, and occupies less floor space, making it more efficient in terms of warehouse area usage. Additionally, it accommodates a greater number of rolls than datum, increasing storage capacity.

3.4 Warehouse Layout Decision

The current layout with 18 racks presents operational inefficiencies, including blocked access ways and excessive forklift backtracking. Two new layouts were conceptualized and compared using the Decision Matrix

Table 4: Decision Matrix.



Rack Layout 1 in 2D

Rack Layout 2 in 2D

Criteria	Weight	Layout Option 1	Layout Option 2	Comments / Notes
Easier Picking Route, reduces backtrack	0.25	3	5	Layout 2 has smoother picking path with less backtracking
Space Utilization	0.2	3	4	Layout 2 uses space more efficiently
Improved Safety: Fewer sharp turns	0.15	2	4	Layout 2 reduces sharp turns, lowering accident risk
Material Handling Efficiency	0.15	3	5	Layout 2 facilitates faster movement of materials
Storage that Supports Product Classification	0.15	3	4	Layout 2 better supports organizing by product type
Adaptability to Changing Inventory and Needs	0.1	2	4	Layout 2 is more flexible and scalable
Weighted Score	1	2.75	4.4	

Layout 2 is clearly a better choice compared to Layout 1 based on the decision matrix evaluation. It offers a smoother picking route, which significantly reduces backtracking and improves overall efficiency. Additionally, Layout 2 utilizes space more effectively, allowing for better storage capacity within the warehouse. Safety is also enhanced with Layout 2, as it reduces the number of sharp turns, thereby lowering the risk of accidents. In terms of material handling, Layout 2 facilitates faster and more efficient movement of goods. It also supports better product classification, making it easier to organize inventory by type. Furthermore, Layout 2 is more adaptable to changing inventory demands and operational needs, offering greater flexibility and scalability. Overall, with a higher weighted score, Layout 2 provides superior performance across all key criteria, making it the more practical and efficient layout for warehouse operations.

3.5 3D Warehouse Layout and Space Utilization

The warehouse area is 940.12 m², The 3D model developed in Coohom illustrates improved spatial organization and rack positioning

Table 5: Visualization of Item on the floor in Old VS New Layout

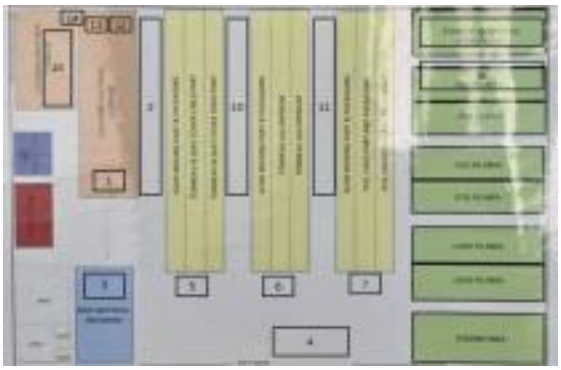
Old Layout	New Layout
	

Table 6: Space Utilization Analysis of the Old Layout vs New Layout.

No.	Location	Length (m)	Width (m)	SQM (m²)
1	Pallet stack near QC	3.2	1.6	5.1
2	Packaging material on the floor	11.7	4	46.8
3	Receiving Area	6	6	36
4	Box in front of door	12	4	48
5	Box in front of rack first	1.86	1.16	2.2
6	Box in front of rack second	3.79	1.2	4.5
7	Box in front of rack third	2.4	1.2	2.9
8	Boxes at the back	14.64	3.4	49.8
9	Item between Rack 1	10.46	1.65	17.3
10	Item between Rack 2	11.53	2.12	24.4
11	Carpet RU	12.56	3.97	49.9
12	Item BD	2.2	0.97	2.1
13	STD and TMCA	2.26	0.97	2.2
14	Foam JL and Lucid	1.7	0.98	1.7
15	PVC/PUR/ GREEN	11.5	2.5	28.75
	Total SQM	321.65		

Item on the floor in the old layout

No	Length (m)	Width (m)	SQM
1	3.7	3.3	12.21
2	10.6	1.75	18.55
3	20	3.3	66
4	12.5	2.8	35
5	2	12.5	25
6	2.5	1.6	4
7	2.5	1.6	4
8	1.25	1.55	1.9375
Total SQM	166.6975		

Item on the floor in new layout

$$\frac{321.65}{940.12} \times 100 = 34.21\%$$

$$\frac{166.70}{940.12} \times 100 = 17.73\%$$

Percentage of Items on the floor (Difference)

$$34.21\% - 17.73\% = 16.48\%$$

3.6 FSN Inventory Classification.

FSN analysis categorized inventory into Fast (24.7%), Slow (50%), and Non-moving (25.3%) parts. Location identifiers were assigned accordingly, with fast-moving items placed in bottom rack slots for quick access, slow-moving items in middle slots, and non-moving items in upper racks or dedicated storage.

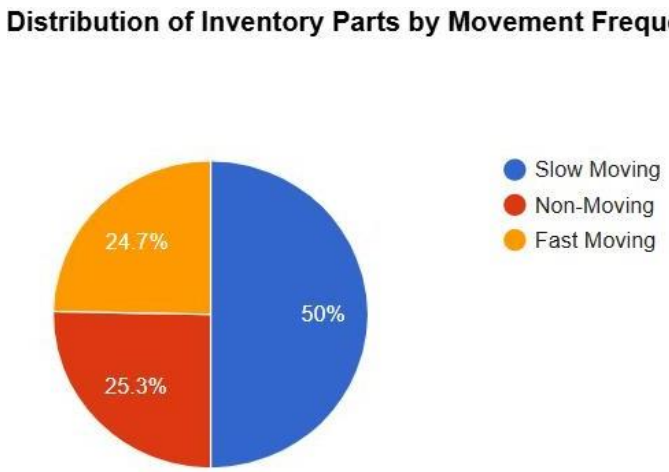


Figure 3: Distribution of Inventory Part by Movement Frequency.

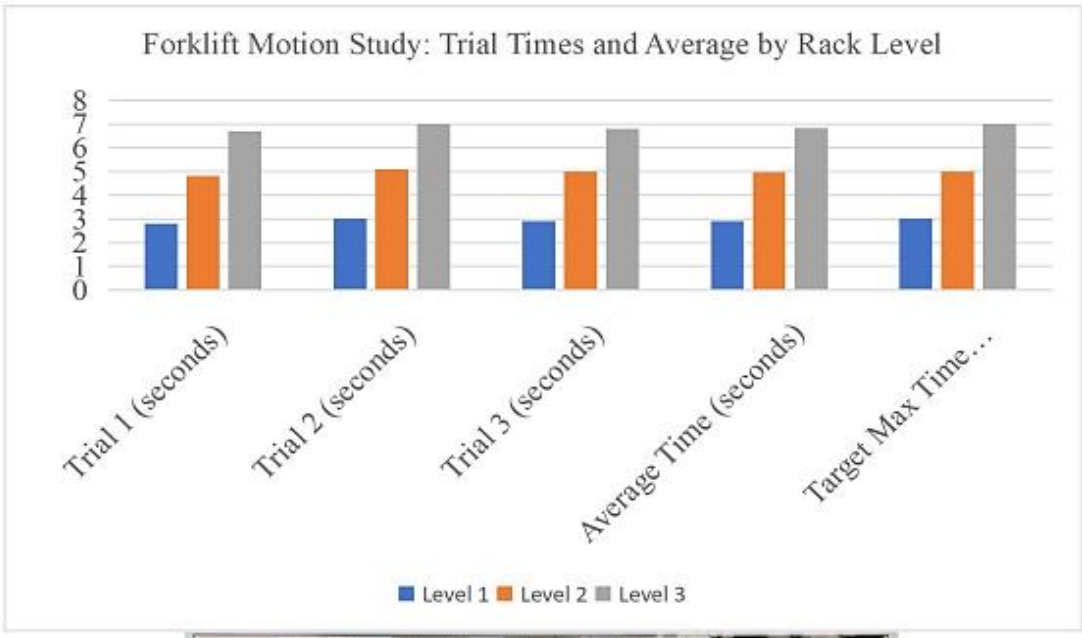
Table 7 : Location Identifiers.

Description	Location
Laminated Covering Material	LC 1 (The number shows which rack)
Unlaminated Covering Material	ULC1 (The number shows which rack)
Packaging Material Racks	R1 – 45 slots Bottom Rack – slots B1-B15 Middle Rack – slots M16 –M30 Top Rack – slots T31-T45 R2 – 45 slots Bottom Rack – slots B1-B15 Middle Rack – slots M16 –M30 Top Rack – slots T31-T45
T/SC and TESLA Racks	R3 – 45 slots Bottom Rack – slots B1-B15 Middle Rack – slots M16 –M30 Top Rack – slots T31-T45
	R4 –45 slots Bottom Rack – slots B1-B15 Middle Rack – slots M16 –M30 Top Rack – slots T31-T45
RU / LUCID / JL Racks	R5 – 45 slots Bottom Rack – slots B1-B15 Middle Rack – slots M16 –M30 Top Rack – slots T31-T45
RU Carpet	F1
STD & TMCA	F2
TESLA CARPET	F3
Non Moving Storage	NMS

3.7 Forklift Motion and Picking Time Analysis.

A forklift motion study measured times to reach different rack levels, with times increasing from 2.9 seconds at the bottom to 6.83 seconds at the top level. Forklift speed was limited to 3 km/h for safety. Picking time samples were collected in the current layout and visualized. Distances were measured in Coohom for accurate analysis. In the new layout, picking times incorporating forklift motion showed significant improvements across all FSN classes. The percentage improvement ranged from 10.1% to 24.15% compared to the old layout, exceeding the project target of a 10% increase in storage efficiency and reduction in picking time.

Figure 4: Forklift Motion Study: Trial Times and Average by Rack Level.



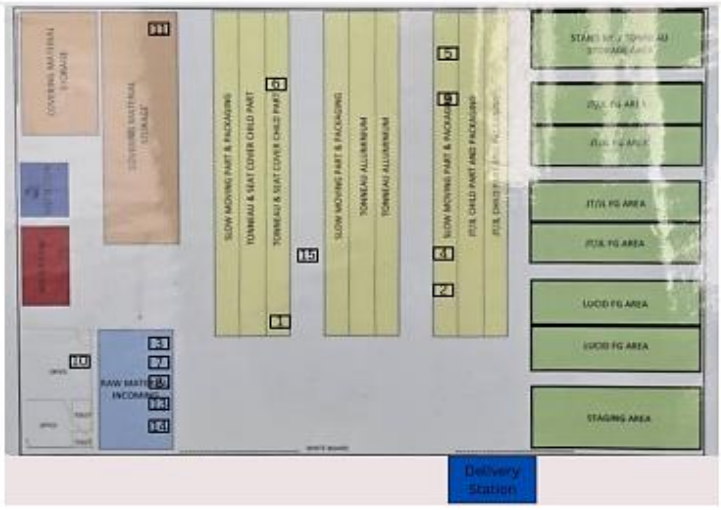


Figure 5: Visualization of Items Used as sample for Picking Time

The comparison between the average picking times before improvement and the time taken after implementing item classification based on movement frequency and assigning unique location identifiers reveals promising results. The objective was to achieve a reduction in picking times ranging from 10% to 15%. The data shows that most items experienced improvements within or above this target range.

Table 8: Picking Time Analysis

Part Number	FSN Class	Location ID	Rack Level	Average Time (Before) (s)	Forklift Motion (s)	Time Taken (After) (s)	Time Taken + Forklift Motion (After) (s)	Improvement in Time (%)
5-0516JV	F	R1-B1	1	14.36	2.9	10.01	12.91	10.1
6-0506JV	F	R1-B2	1	16.62	2.9	11.55	14.45	13.06
6-4375RU	F	R1-B3	1	19.29	2.9	13.04	15.94	17.37
9-1073JV	F	R1-B4	1	22.74	2.9	14.86	17.76	21.9
9-1044JV	F	R1-B5	1	25.14	2.9	16.22	19.12	23.95
6-4380RU	S	R1-M16	2	16.7	5.0	10.01	15.01	10.12
8-1545JV	S	R1-M17	2	19.03	5.0	11.55	16.55	13.03
5-0528RU	S	R1-M18	2	21.83	5.0	13.04	18.04	17.36
6-4385RU	S	R1-M19	2	25.42	5.0	14.86	19.86	21.87
6-4383RU	S	R1-M20	2	27.97	5.0	16.22	21.22	24.13
1-0503JV	N	R1-T31	3	18.73	6.83	10.01	16.84	10.09
6-0504JV	N	R1-T32	3	21.14	6.83	11.55	18.38	13.06
8-1548JV	N	R1-T33	3	24.04	6.83	13.04	19.87	17.35
6-4388RU	N	R1-T34	3	27.74	6.83	14.86	21.69	21.81
6-4386RU	N	R1-T35	3	30.39	6.83	16.22	23.05	24.15

2.1 Discussion

The results confirm that the systematic reorganization of inventory based on FSN classification, combined with optimized racking and warehouse layout, substantially enhances storage space utilization and operational efficiency. Questionnaire feedback highlighted critical issues, which were directly addressed through layout redesign and strategic item placement. The significant reduction in floor clutter and improvement in picking times demonstrates the effectiveness of this integrated approach. These findings align with prior studies emphasizing the importance of layout optimization and inventory classification in warehouse performance improvement. The reduction in forklift travel time and safer aisle design further contribute to productivity gains and risk mitigation. Overall, the study successfully achieved the objective of increasing warehouse storage efficiency by more than 10%, demonstrating a scalable model for similar industrial settings.

4.0 CONCLUSION

This study aimed to enhance warehouse efficiency by addressing key issues such as prolonged picking times, inaccurate cycle counting, and poor space utilization. The research applied FSN (Fast, Slow, Non-moving) inventory classification, warehouse layout redesign, and simulation-based evaluation. Key bottlenecks, including inefficient rack placement, poor aisle design, and the lack of unique location identifiers, were identified and resolved.

By reorganizing inventory based on movement frequency, the warehouse prioritized fast- moving items in easily accessible areas, while slow- and non-moving stock was relegated to less accessible zones. The adoption of cluster storage and a U-shaped layout improved workflow and reduced picking errors. Results showed a 10-15% improvement in picking times and more than 10% increase in space utilization, meeting the study's objectives. The new layout also optimized space utilization by increasing rack numbers and vertical storage. Overall, the study demonstrates that a data-driven approach combining FSN analysis, layout redesign, and simulation modelling can significantly enhance warehouse performance, reduce labour costs, and support growth.

5.0 ACKNOWLEDGMENT

I would like to extend my sincere appreciation to all those who contributed to the successful completion of this project. First and foremost, I am deeply grateful to my project supervisor, Encik Mohd Nazri Bin Mohd Sabri, for his expert guidance, constructive criticism, and unwavering support throughout this research. His knowledge and encouragement significantly enhanced the quality of this work. My thanks also go to the academic and administrative staff of the Mechanical Department of Ungku Omar Polytechnic for providing the necessary facilities and academic environment. I am also thankful management and staff of the company for granting access to the warehouse and sharing crucial data for the FSN analysis and simulation components.

I appreciate the teamwork and cooperation of my classmates throughout the project. Lastly, I would like to acknowledge my family and friends for their constant encouragement and moral support, which motivated me to complete this endeavour successfully. To all who have contributed, your help has been greatly appreciated.

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Process Optimization in PET Bottle Manufacturing: Enhancing 1.5L Bottle Quality through Mould Redesign and Booster Implementation

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ABSTRACT

This study investigates the underlying causes of quality defects in the 1.5 litre polyethylene terephthalate (PET) bottle blow moulding process at a manufacturing company that supplies the beverage industry for both local and international markets, with particular emphasis on the JS2000 blow moulding machine. The main issue identified was a drop in air pressure caused by leakage between the base mould resulting in improper bottle formation, reduced production efficiency, and increased material waste. This study aims to precisely identify the specific issues encountered in the blow moulding process and to enhance the quality of the final product by up to 80%. The study focused on the production of 1.5L PET bottles using a newly designed mould, accompanied by the integration of a booster to the high-pressure air compressor system with a value of up to 40 bar. After implementing these changes, several key quality tests were repeated, including wall thickness testing, the brim-full test and crack test which assesses the maximum fill volume before overflow occurs. This test is very important to ensure there is no waste of preform and to prevent cracks in the base of the bottle. Results showed an 93.2% improvement in bottle quality compared to the pre project condition, which only achieved 60% acceptance level and a reduction of nearly 45% in average daily defects. Additionally, material waste was reduced by 40%, and the machine's efficiency significantly increased. This study contributes to industrial practice by enhancing production output while simultaneously reducing operational costs and achieving higher quality standards. Moreover, the improvements contribute to the competitiveness of the local manufacturing sector and promote sustainable resource utilization in alignment with national development goals.

Keywords: blow moulding, mould redesign, pressure optimization, PET bottle, quality improvement

1.0 INTRODUCTION

The demand for high-quality polyethylene terephthalate (PET) bottles continues to rise, particularly in the beverage, pharmaceutical, and personal care industries. Blow moulding is a widely used process in the manufacturing of PET bottles, particularly in the beverage industry, due to its efficiency and ability to produce lightweight, durable containers. However, several studies have highlighted that product quality especially in terms of structural integrity at the bottle base can be compromised due to variations in mould design, air pressure, and temperature control during the forming stage (Gomez et al., 2019). The bottle base, being the most stressed region due to internal pressure from carbonated contents, is highly susceptible to folding, deformation, and cracking if not properly formed (Singh & Kaur, 2021).

According to Han and Kim (2020), the design of the mould plays a significant role in distributing stress evenly across the bottle during the blowing process. Improper mould geometry can lead to uneven material stretching, resulting in thin walls and weak base areas. Enhancements in mould design such as dome curvature, base thickness, and push-up structure can significantly improve mechanical strength.

Air pressure is another critical parameter in the blow moulding process. High-pressure air, typically ranging from 35–40 bar, is used to stretch the preform into its final shape. Studies by Zhang et al. (2018) indicate that inadequate or fluctuating air pressure during the blowing cycle leads to insufficient material distribution and increased internal stresses, especially at the base. The use of boosters and precision compressors can help maintain consistent pressure, thereby reducing defects. Additionally, the role of machine performance and process stability is well documented.

Advanced blow moulding systems, such as the JS2000, when equipped with optimized settings and enhancements like boosters and new moulds, show improved product consistency and a reduction in rejection rates (Lee & Park, 2022). These modifications also contribute to better control over wall thickness distribution and base formation. Overall, the literature suggests that improving PET bottle quality particularly minimizing base cracking requires a holistic approach involving mould design optimization, air pressure control, and machine performance evaluation. By addressing these factors, manufacturers can achieve significant improvements in product reliability, aligning with quality goals such as an 80% reduction in defects

This study aims to investigate the root causes of these inefficiencies by focusing on process level issues in the production of 1.5-litre PET bottles. Through targeted interventions, including the redesign of the mould with an internal dome profile and the integration of a booster compressor system, the study seeks to improve air distribution during blowing, enhance bottle base strength, and reduce the occurrence of defects. Quality performance is assessed through a series of post-intervention tests, including wall thickness, brim-full capacity, and crack resistance evaluations.

2.0 METHODOLOGY

This internal investigation was carried out to evaluate the structural integrity and overall performance of the newly produced 1.5 litre PET bottles manufactured using a new mould and booster. The primary objective was to ensure that the new production setup consistently yields bottles that meet quality standards and are free from defects such as cracks or structural weaknesses.

The investigation began with a review of the changes introduced to the production process, specifically the implementation of the new mould design and the booster system. Technical specifications of the mould and machine parameters were assessed to ensure they align with the design requirements for the 1.5 litre format.

Following this, a batch of bottles produced under the new setup was selected for physical testing. Three key quality tests were conducted which are brim-full test to measure the maximum volume capacity of the bottle and ensure it meets volume specifications without compromising structural stability. Wall thickness test to assess uniformity and strength of the bottle walls, ensuring adequate material distribution during the blowing process. Other than that, crack test to detect any visible or hidden cracks that could lead to product failure during filling, transportation, or handling.

2.1 Flow Chart

The project development process followed a structured and iterative planning model, as illustrated in the flowchart of Figure 1. The initial phase involved a discussion with the assigned

mentor to explore potential research areas, assess feasibility, and align the proposed topic with academic and industrial relevance. Following this consultation, the problem statement and research objectives were clearly defined, serving as the foundation for the study's direction. Once the scope and aims were established, an appropriate project title was selected to reflect the focus and expected contribution of the research. A comprehensive literature review was then conducted to examine existing studies, theories, and practices related to the topic, thereby identifying knowledge gaps and supporting the novelty of the proposed work.

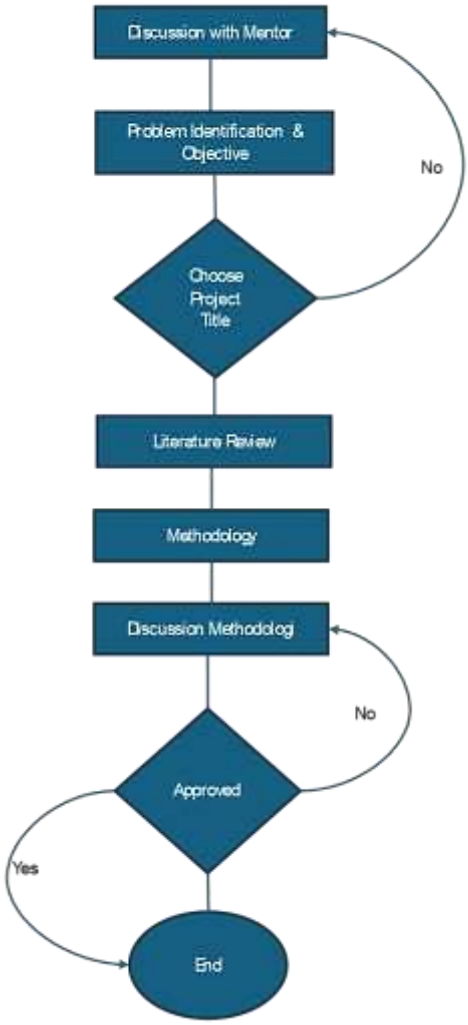

Figure 1: Process flow for achieving the objective

Subsequently, the methodology section was formulated, detailing the approach to data collection, analysis techniques, and tools required to achieve the research objectives. This proposed methodology was then discussed in-depth with the mentor to ensure its validity, practicality, and alignment with academic standards. Revisions were made where necessary based on feedback. Upon final review and approval by the supervising authority, the project was officially endorsed, allowing for progression to the implementation stage. The flowchart also highlights iterative loops between stages, indicating the reflective nature of the process. Such feedback mechanisms are crucial to refining each phase before formal approval, thereby enhancing the overall rigour and coherence of the research plan.

2.2 Application of Booster

A booster is an additional component in a blow moulding machine such as the JS2000 that functions to increase the blowing pressure to ensure that the preform expands fully according to the mould shape, including critical parts such as the base and shoulder of the bottle. After installing a new booster, two important parameters, namely pressure and time, need to be calculated and readjusted to ensure the quality of the bottle formation.

Booster pressure that is too low can cause imperfect bottle formation (mis blow, thin wall, or folds). Conversely, pressure that is too high can cause uneven wall thickness or bottles that are too stretched and weak. Calculating pressure allows technicians to set optimal pressure limits so as not to exceed the capacity of the mould or other parts of the machine, which can cause damage or air leaks.

The appropriate pressure depends on the design and depth of the new mould. Therefore, recalculation of the pressure is required to adjust the blowing energy to match the contours of the new mould. The correct booster pressure helps produce bottles with sufficiently thick and strong walls, especially at the bottom (base) which is often a weak point.

2.3 Implement the New Mould

It is necessary to modify a number of important parameters, particularly blowing pressure and blowing duration, when using a fresh mould in a blow moulding machine like the JS2000. A new mould is a newly created mould that has precise depths, shapes, and contours in accordance with the intended bottle specifications, including the neck, shoulder, and base of the bottle. When a product's design changes, the market demands a different bottle shape, or packaging developments call for a more aesthetically pleasing or ergonomic bottle shape, this new mould is usually utilised.

The technical specifications for each new mould vary based on the size of the cavity, the desired wall thickness, and intricate designs that call for more precise airflow patterns or higher blowing pressure. In order to guarantee that the blowing pressure and blowing time are in line with the mould design, installing a new mould entails more than just replacing the physical component. If these criteria are not changed, there is a greater chance of creating bottles with flaws such weak bases that are prone to breaking, too thin walls, or irregular shapes.

The booster is crucial in this situation because it supplies the extra pressure required to guarantee that the compressed air can completely push the preform to fill all of the gaps in the new mould. The bottle forming process can proceed smoothly and produce sturdy, high quality bottles that satisfy the requirements of the new mould provided the proper pressure and timing are established.

2.4 Brimfull Test

After implementing changes in the 1.5 liter bottle production process by replacing the old with a new mould and adding a booster to the JS2000 blow moulding machine, it was very important to re run the quality test on the produced bottles. Among the main tests that needed attention were the wall thickness test and brim-full test.

Brim-full refers to the maximum capacity of liquid that can be filled into a bottle up to the highest level without overflowing. Changes in the mould shape, even slightly, can affect the internal volume of the bottle. Although the nominal capacity of the bottle is 1.5 litre, the brim-full capacity may change depending on the neck shape, shoulder steepness and depth of the base.

Brim-full test gives a true picture of the maximum amount of liquid that can be inserted before the risk of overflow occurs, especially in the automatic filling process in the filling line. This is important to ensure that there is no overfill that can cause leakage at the cap or contamination of other products.

After a pressure change through the booster, the final shape of the bottle may differ slightly from the previous bottle. Brim-full testing will help identify whether the bottles produced still meet the volumetric tolerances set by QA or customer standards. Accurate brim-full capacity is also important to ensure the bottle is not overfilled which can put additional pressure on the cap and increase the risk of leakage during transport.

2.5 Wall Thickness Test

Wall thickness refers to the thickness of the plastic wall of the bottle at various points such as the neck, mid body, shoulders, and especially the base. The new mould is likely to have a different design than the previous one, including dimensions, base shape, and the expansion pressure required. This will affect how the plastic from the preform spreads across the surface of the mould.

The addition of a booster increases the air pressure in the blow moulding process. This causes the preform to expand more aggressively. If the pressure is not controlled, it can cause the wall to be too thin in some areas and too thick in others.

Uneven wall thickness can cause the bottle to weaken at certain points, especially in high-stress areas such as the base. This can cause dents, leaks, or cracks when the bottle is filled or stacked during storage.

This test ensures that the bottle wall thickness is within the specified technical specifications (usually within the minimum and maximum thickness ranges in micrometres) to ensure it can withstand internal pressure and external loads.

2.6 Crack Test

Crack test on 1.5 litre bottles refers to a test to detect small cracks or defects on the surface of the bottle usually performed on plastic bottles (such as PET) or glass bottles to ensure there is no risk of leakage, breakage, or structural failure during use. Crack testing is important after implementing process changes such as using a new mould and adding a booster because both factors can significantly impact the structural integrity of a 1.5 litre bottle.

A new mould can change the material flow and wall thickness distribution, while a booster can change the mechanical properties of the plastic, potentially leading to brittleness or internal stress. These changes increase the risk of cracking, leaking, or failure under stress. Performing

crack testing helps confirm that the new process setup maintains the required quality and safety standards, prevents product defects, and ensures compliance with quality assurance and regulatory requirements before full scale production begins.

3.0 RESULTS AND DISCUSSION

After the implementation of the new mould and the addition of a booster to the compressor on April 24, 2025, the production data for the 1.5 litre bottles at Company A showed a significant improvement in quality control performance. These improvement actions were the result of a prior internal investigation aimed at reducing the high rate of defective bottles, particularly those with cracks and folded surfaces.

Table 1: Daily QC Verification of Scrap – Comparison Between Old and New Mould Designs

No.	Date	Old Mould (Crack) Quantity (pieces)	New Mould Crack Quantity (pieces)
1.	8/1/25	680	-
2.	9/1/25	41	-
3.	12/1/25	49	-
4.	13/1/25	351	-
5.	15/1/25	149	-
6.	14/1/25	339	-
7.	23/1/25	141	-
8.	26/1/25	48	-
9.	28/1/25	181	-
10.	30/1/25	11	-
11.	2/2/25	204	-
12.	3/2/25	106	-
13.	10/2/25	12	-
14.	12/2/25	350	-
15.	1/3/25	49	-
16.	2/3/25	23	-
17.	3/3/25	72	-
18.	5/3/25	72	-
19.	24/3/25	17	-
20.	21/4/25	166	-
22.	22/4/25	50	-
21.	23/4/25	35	-
22.	4/5/25	0	175
23.	5/5/25	0	11
24.	18/5/25	0	22
Total		3062	208

Table 1 and Figure 2 presents the scrap data used to compare the performance of the old mould design versus the new mould design, specifically in identifying bottle damage or losses during production. The table summarizes daily QC (Quality Control) verification of rejected bottles, categorised by the mould type. Before the improvements were introduced, records show that the old mould caused a total of 3062 defective bottles between early January and mid April 2025, mostly due to cracks and folding defects. In fact, the Quality Control (QC) department was unable to track the total number of defective bottles before January 2025 due to the excessive accumulation of defective bottles that had already passed through production without proper inspection.

However, after the new mould and booster were introduced on April 24, 2025, the number of defective bottles dropped dramatically to only 208 units. More importantly, the defects recorded after this improvement were no longer due to structural issues such as cracked bases or folding, but rather from typical issues like improper blowing or initial temperature setting errors common operational problems that are considered manageable with routine monitoring.

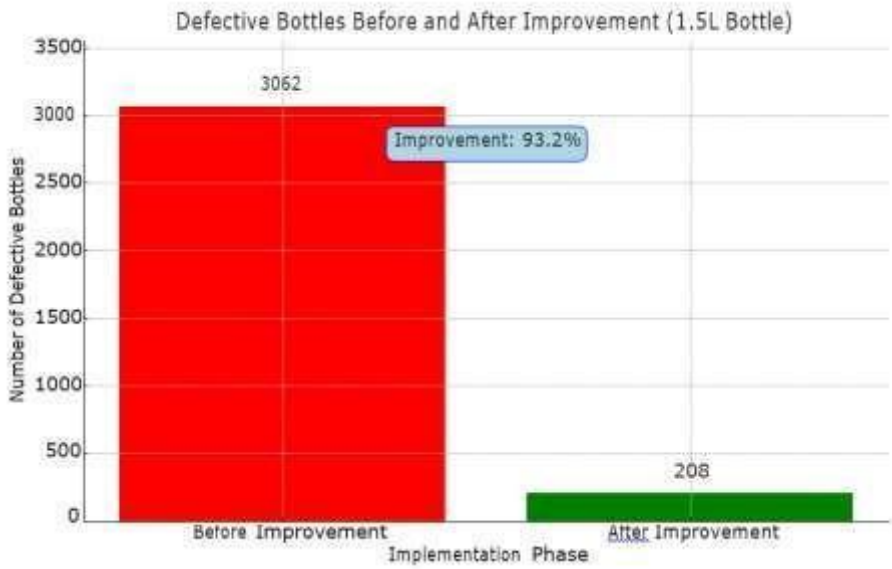

Figure 2: Total Defective Bottle Quantity: Old vs New Mould

Based on the daily scrap data recorded over 24 days, a clear improvement in production quality is evident after transitioning from the old to the new mould design. The total number of defective bottles recorded using the old mould was 3062 units, with an average of approximately 126 defects per day. In contrast, the new mould recorded only 208 defective bottles across the same observation period, with an average of 69 defects per day, a reduction of nearly 45% in average daily defects.

Figure 3 shows a line graph comparing the daily quantity of defective bottles produced using the old mould versus the new mould. The highest single-day defect count with the old mould reached 680 units, whereas the new mould's maximum was substantially lower at 175 units. Additionally, the minimum recorded defects dropped from 0 units with the old mould to 11 units with the new mould, suggesting greater consistency in quality control. It clearly illustrates the

significant reduction in defects following the implementation of the new mould design, supporting the effectiveness of the improvement measures.

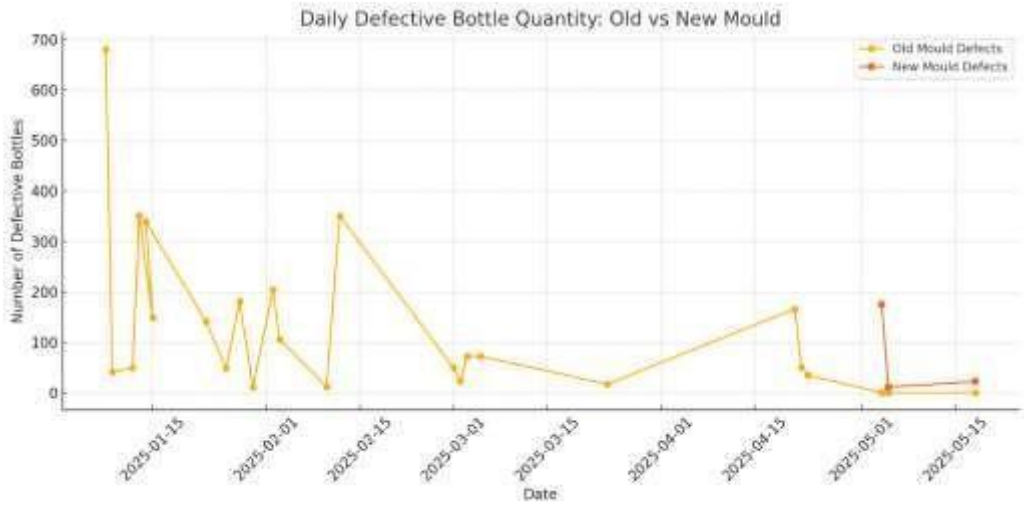

Figure 3: Daily Defective Bottle Quantity: Old vs New Mould

This data substantiates the positive impact of implementing the new mould design and booster system, aligning with the study's reported 93.2% improvement in overall product quality and supporting its conclusion regarding enhanced process stability and reduced material waste. These findings clearly demonstrate that the corrective actions taken were not only effective in reducing the defective bottle rate but also contributed to process stability, increased productivity, and helped cultivate a more systematic and quality focused work culture among operators and the QC team.

4.0 CONCLUSION

In conclusion, the "Internal Investigation of 1.5 Litre Bottle" has produced highly positive results and successfully achieved its main goals in improving product quality and production process efficiency. Through this investigation, the company was able to accurately identify the root causes of defective and folded bottles, which previously led to significant material wastage, particularly in the form of unusable preforms. The corrective actions implemented, such as the use of a new mould, adjustments in, and the addition of a compressor booster, have yielded remarkable improvements.

Regarding the objective, post implementation data shows that the final product quality has increased beyond expectations by 93.2%, exceeding the original target of 80% and a reduction of nearly 45% in average daily defects. This includes a reduction in reject rates, greater consistency in bottle size and shape, and better conformity to weight and volume specifications.

In summary, this study has not only resolved the technical issues previously faced, but also brought significant benefits in terms of reducing waste, improving yield, and ensuring smooth production flow. The success in achieving an 93.2% improvement proves that the approach taken was effective and should serve as a REFERENCES for future process enhancements.

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R05 – Improvement To Reduce Position NG (01005)

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ABSTRACT

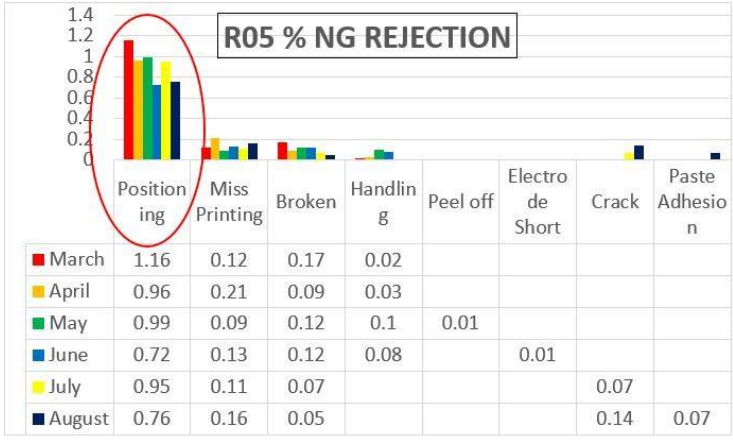
This project focuses on reducing position-related non-conformities (Position NG) in substrate 01005 components. Position NG issues primarily stem from deviations in critical manufacturing processes, such as upper and lower cross mark scribing and electrode printing. These deviations result in misalignment, which negatively affects product performance and reliability. The study aims to investigate the R05 process and identify root causes of positional inaccuracies using tools like fishbone diagrams, fault tree analysis, and root cause analysis, with emphasis on machine calibration, material handling, and environmental factors. Key findings highlight that inconsistent scribing depth, poor mark alignment, and variations in electrode material application are major contributors to these issues. As a solution, process optimizations were implemented, focusing on improving cross mark scribing precision and enhancing control during electrode printing. The project also integrated Statistical Process Control (SPC) and real-time monitoring to reduce variability and ensure stable production quality. These improvements led to a noticeable decrease in Position NG occurrences, reinforcing the company's dedication to quality, process excellence, and continuous improvement in manufacturing.
Keywords: Improvement, Position NG, Substrate 01005, Cross Mark Scribe

1.0 INTRODUCTION

Process R05 involves a sequence of precise steps in the manufacturing of electronic components, specifically focusing on the handling of 01005-sized parts, which are extremely small and prone to positional defects (NG: No Good). The process includes upper mark scribing, lower first mark scribing, colouring for visual contrast, lower and upper electrode printing, and final inspection. Each of these steps plays a critical role in ensuring accurate alignment and placement. Improving this process aims to reduce position-related NGs by enhancing mark clarity, scribing accuracy, and electrode alignment, which are essential for achieving the high precision required in 01005 component production.

1.1 PROBLEM STATEMENT

The R05 % NG Rejection data from figure 1.2 shows that positioning is the most significant and consistent contributor to defects in 01005 components from March to August, with a peak rejection rate of 1.16% in March. Despite a reduction to 0.76% in August, positioning still leads over other defect categories like miss printing, broken parts, and handling issues. This consistent trend suggests that the root cause is persistent and likely linked to factors such as machine calibration, operator handling, or measurement methods. Other defects like cracks and paste adhesion are minor, reinforcing the need for focused improvements in positioning accuracy.



	Positioning	Miss Printing	Broken	Handling	Peel off	Electrode Short	Crack	Paste Adhesion
March	1.16	0.12	0.17	0.02				
April	0.96	0.21	0.09	0.03				
May	0.99	0.09	0.12	0.1	0.01			
June	0.72	0.13	0.12	0.08		0.01		
July	0.95	0.11	0.07				0.07	
August	0.76	0.16	0.05				0.14	0.07

Figure 1: The highest contribution R05% NG rejection

1.2 OBJECTIVES

To reduce R05 position NG average of 0.95% (March 2024-August 2024) to 0.48% by June 2025

A strategic approach will be implemented, focusing on refining the alignment mechanisms and minimizing variability in the production process. Regular inspections, data-driven adjustments, and preventive maintenance will be prioritized to maintain consistent performance. Enhanced quality controls and real-time monitoring will ensure continuous improvement toward achieving this target. Minimize positioning-related defects in chip production to enhance the overall yield, ensuring higher output of quality products.

2.0 METHODOLOGY

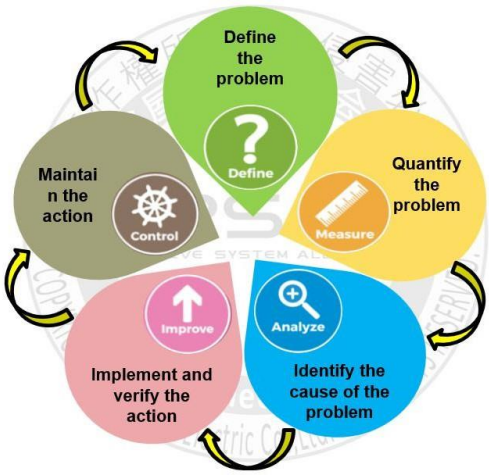


Figure 2.1: DMAIC Methodology

The DMAIC methodology is important in process improvement and defect reduction. The figure 2.1 structured applied to various manufacturing processes, such as scribing, electrode printing and inspection.

I. Define
Identifying issues like high rejection rates in chip production processes.

II. Measure
Collecting data on defect types, defect rates, and machine efficiency.

III. Analyze
Using tools like root cause analysis or Pareto charts to determine why defects occur (example: poor alignment during scribing).

IV. Improve
Implementing corrective actions such as machine recalibration (improvement 6 line for positioning issues) or operator retraining.

V. Control
Standardizing new procedures and monitoring key metrics to ensure sustained improvements.

Define

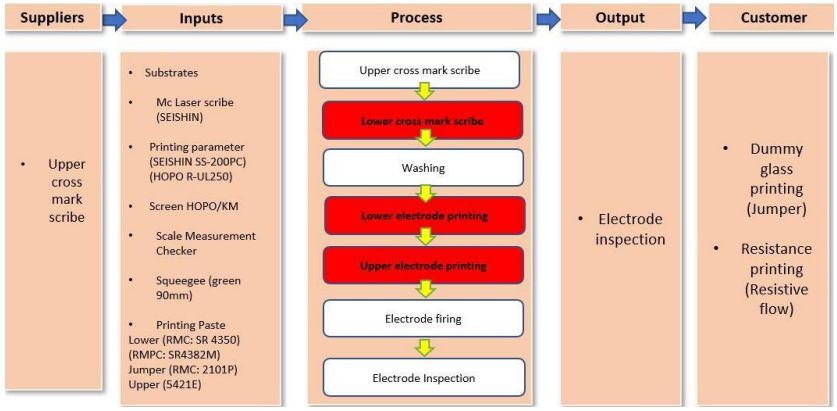


Figure 2.2: SIPOC Diagram

The R05 process flow depicted in the figure 2.2 outlines the critical steps involved in electrode printing for miniature components, particularly 01005-sized parts. It begins with upper cross mark scribing, followed by lower cross mark scribing, which are essential for alignment and positioning throughout the process. After scribing, a washing step removes any debris or contamination to ensure a clean surface for printing. The process continues with lower electrode printing and then upper electrode printing, both of which are precision-driven tasks requiring consistent printing parameters, screens, and high-quality paste to ensure accuracy. Electrode firing is then performed to solidify the printed electrodes, followed by electrode inspection to verify alignment, print quality, and the absence of defects.

The inputs section highlights the materials and equipment used, including substrates, laser scribe machines (e.g., SEISHIN), printing pastes (such as RMC and RMPC types), squeegees, and screens. These inputs must be tightly controlled to minimize variability that can lead to positional defects, particularly critical for 01005 parts due to their extremely small size. The output of this process is a thoroughly inspected printed electrode, which is passed on to subsequent processes like dummy glass printing (Jumper) or resistance printing (Resistive flow). By improving alignment accuracy during the scribing and printing steps, manufacturers can significantly reduce "position NG" (No Good) issues and ensure high reliability in microelectronic component production.

Measure

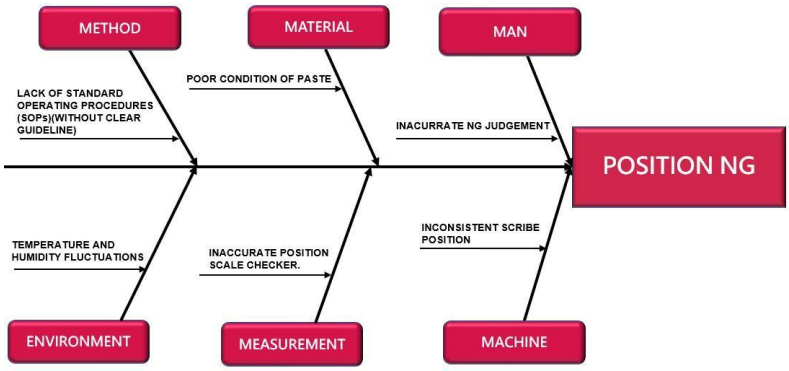


Figure 2.3: Fishbone of Position NG

The fishbone diagram (Ishikawa diagram) in the figure 2.3 identifies the root causes contributing to Position NG (No Good) issues during the R05 process. The problem is broken down into six main categories: Method, Material, Man, Machine, Measurement, and Environment. Under Method, the lack of standardized operating procedures (SOPs) or unclear guidelines can lead to inconsistencies during the process, directly affecting part positioning. Material issues include the poor condition of paste, which can result in printing defects or misalignment. Under Man, inaccurate NG judgement by operators leads to inconsistent defect classification, which can mask real process issues.

The Machine category highlights the impact of inconsistent scribe positions, likely caused by equipment variation or misalignment, which is critical for accurate part placement in microelectronics like 01005 components. Measurement inaccuracies, such as errors from the position scale checker, also contribute to position defects by giving false feedback on alignment. Finally, Environmental factors such as temperature and humidity fluctuations can affect material behaviour and equipment performance, leading to shifts in component placement. Addressing these interconnected root causes systematically is key to reducing position NG rates and improving process stability.

Analysis

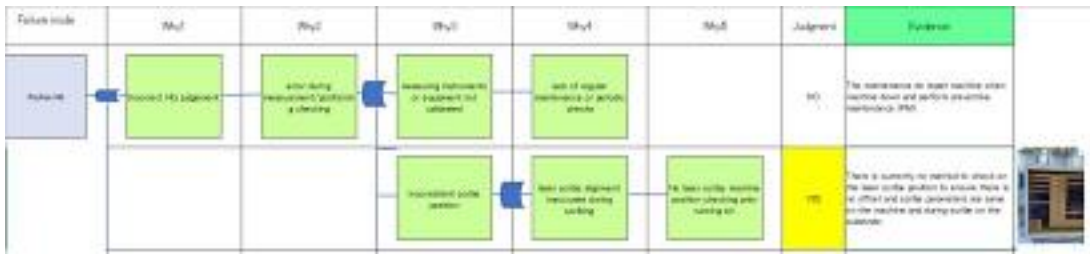


Figure 2.4: 5 why analysis

The analysis shown in the 5 Whys diagram investigates in the figure 2.4 the root causes of Position NG (positional defects) in the R05 process. One main cause identified is incorrect NG judgment, which is traced back to errors in measurement and positioning. This, in turn, is due to uncalibrated measuring instruments or equipment, stemming from a lack of regular maintenance or periodic checks. Another related issue is that operators lack clear guidelines, and quality control is not prioritized during earlier stages of the process. Additionally, quality checks (QC) are only conducted after electrode printing and not during critical earlier steps like scribing, which allows

errors to propagate undetected.

Another root cause identified is inconsistent scribe position, which is linked to inaccurate alignment during the scribing/printing process. This issue is caused by the machine not being re-set or adjusted properly after setup, particularly during usage or after making position adjustments. The judgment column indicates this is a confirmed root cause (marked YES), supported by evidence that operators only adjust the machine's X-position and do not fully re-align it, leading to recurring misalignment issues. This highlights a critical gap in setup practices and machine handling that directly contributes to position NG, calling for procedural and training improvements.

Improvement

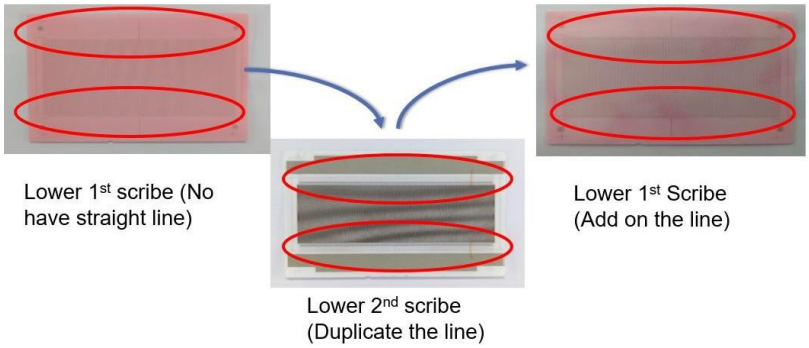


Figure 2.5: Additional new line to product

Figure 2.5 illustrates the improvement of adding straight horizontal lines to the lower 1st scribe, which directly supports the 6-lines measurement method used in the positioning project for 01005 components. Initially, the scribe lacked straight REFERENCES lines, making it difficult to take accurate point to point measurements and contributing to high NG (non-good) rates due to misalignment. By duplicating the lower 2nd scribe and adding clear lines, the process allowed operators to use consistent visual markers for better positioning control. This change enhanced the precision of alignment during production, reduced variation, and made the 6-line measurement method easier to apply. As a result, the improvement helped lower the percentage of position NG by providing stable REFERENCES points, ensuring better quality control and contributing to the overall success of the project.

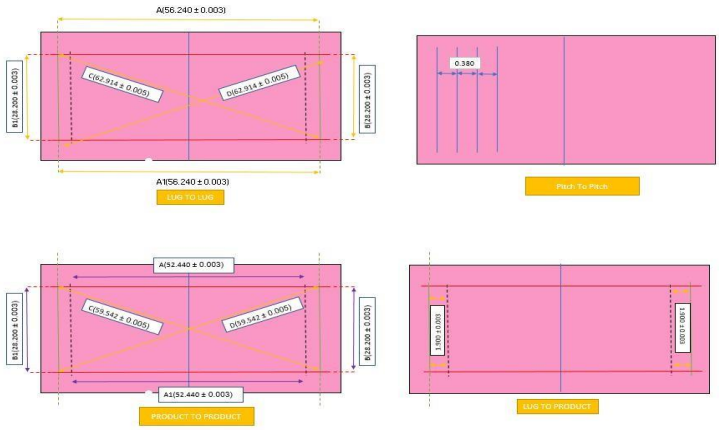


Figure 2.6: Specification and Guidelines 6-lines measurement

Figure 2.6 presents the specification and guideline for the 6-lines measurement method, which is used to control and monitor the accuracy of component positioning in the process. The diagrams show how six key references points are placed across the panel area to assess symmetry, distance, and alignment within tight tolerances (±0.003). These measurement lines allow for precise tracking of any deviation in position, especially for small components like 01005. The "Paste on Panel" and "Side to Side Check" views further support the visual inspection and standardization of setup. By following this structured guideline, operators can consistently measure and adjust positioning, reducing errors and improving quality outcomes across production lots. This methodology is especially effective when combined with improvements like added scribe lines, which help in locating measurement points easily.

Control

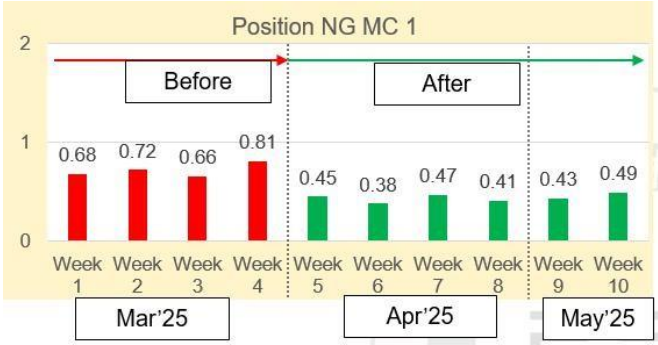
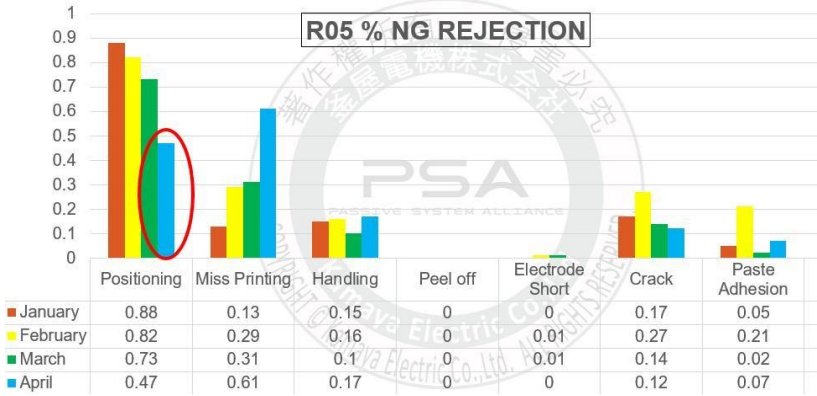


Figure 2.7: Graph machine 1 using 6-lines measurement

Figure 2.7 shows the control graph for Machine 1 before and after implementing the 6- lines measurement method to reduce position NG (non-good) rates. In March 2025 (Weeks 1–4), the position NG values were consistently higher, ranging from 0.66 to 0.81. After applying the 6-lines method starting in April 2025 (Week 5 onward), a significant improvement is seen, with NG values decreasing to between 0.38 and 0.49. This indicates better control of positioning accuracy, likely due to the more precise and consistent measurement points provided by the 6-lines approach. The trend demonstrates that the new method effectively stabilized and lowered the NG rate, supporting better quality and process reliability.

3.0 RESULTS AND DISCUSSION

Result after improvement 6-lines measurement



	Positioning	Miss Printing	Handling	Peel off	Electrode Short	Crack	Paste Adhesion
January	0.88	0.13	0.15	0	0	0.17	0.05
February	0.82	0.29	0.16	0	0.01	0.27	0.21
March	0.73	0.31	0.1	0	0.01	0.14	0.02
April	0.47	0.61	0.17	0	0	0.12	0.07

Figure 3: Graph result after improvement 6-lines improvement

Figure 3.1 presents the R05 % NG rejection results after implementing the 6-lines measurement

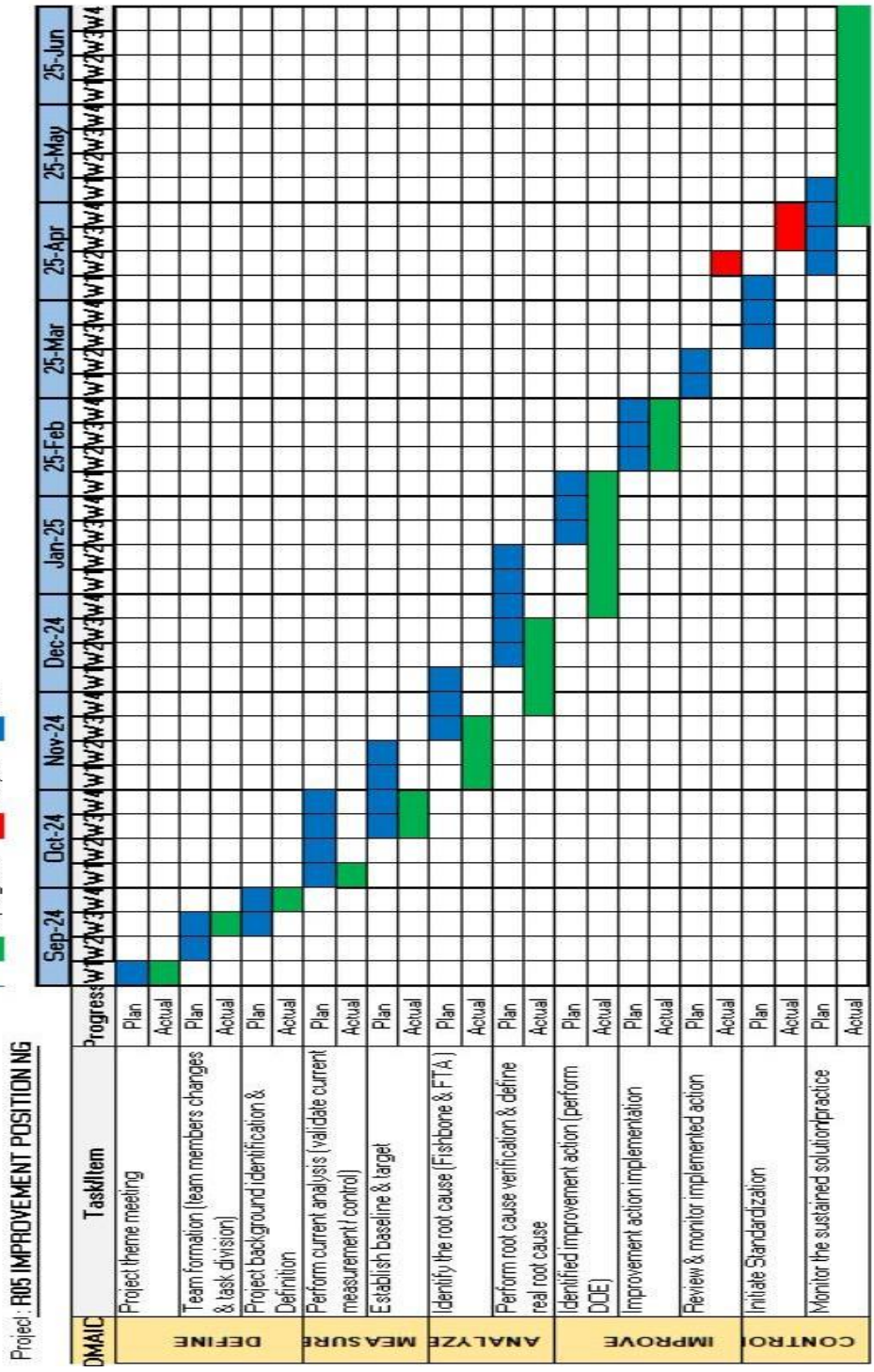
method in 2025. The graph indicates a steady reduction in NG rejection rates for the "Positioning" category from January to April, with values dropping from 0.88 in January to 0.47 in April. Similar improvements are also noted in "Miss Printing" and "Handling," showing the positive impact of the new measurement system. Categories like "Peel off" and "Electrode Short" maintained zero or near-zero rejection rates throughout the period, indicating strong stability in those areas.

The data clearly demonstrate that the implementation of the 6-lines measurement system contributed to a significant reduction in positioning-related NG issues, which had previously been the dominant contributor to overall rejection rates. By enhancing precision in measuring electrode position, the process achieved better accuracy and control, especially in detecting misalignments. This improvement not only reduced defects but also helped stabilize other problem areas like "Miss Printing" and "Handling," supporting the conclusion that better visual guidance and alignment during inspection and placement processes positively affect multiple quality aspects.

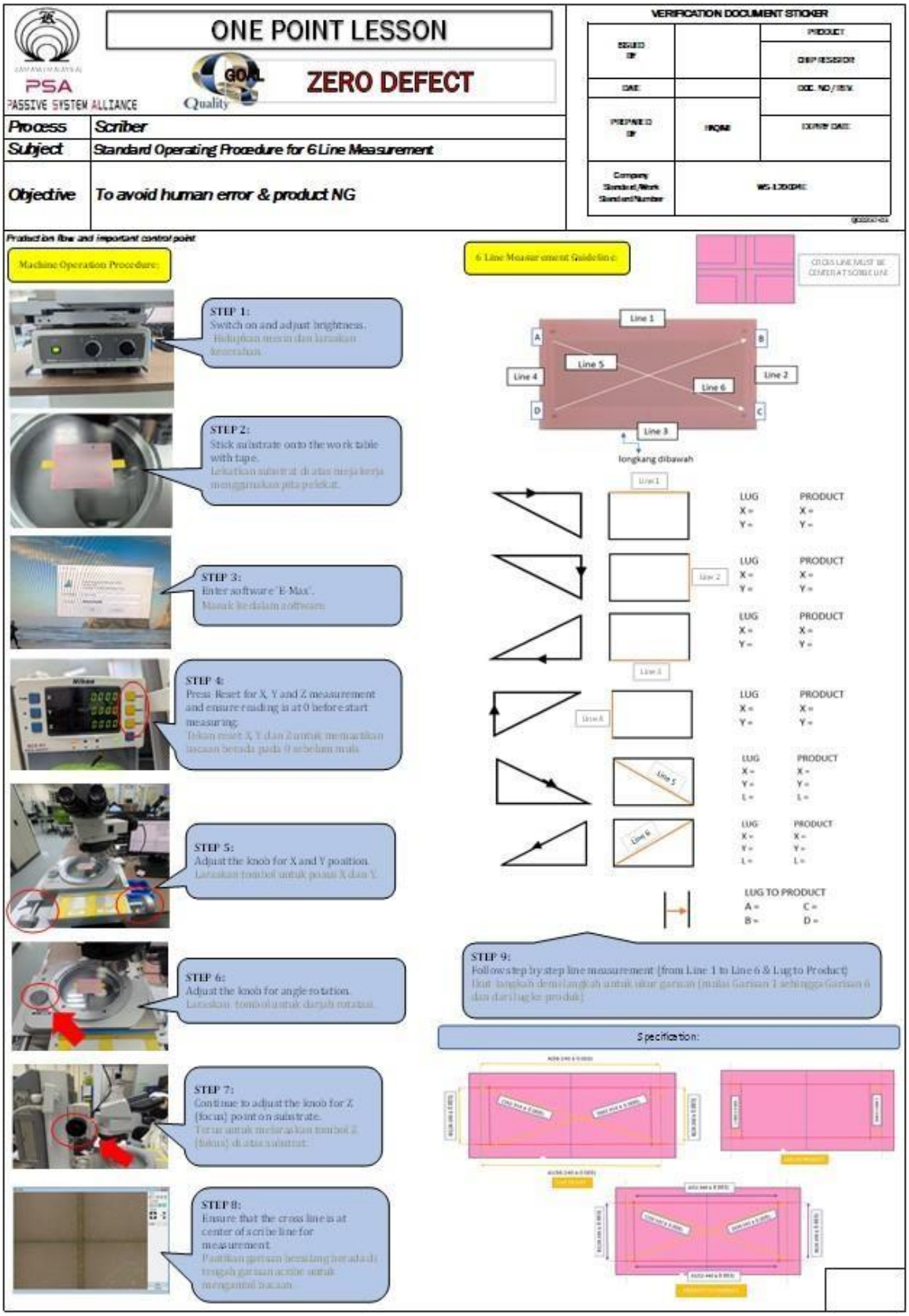
3.0 CONCLUSION

The implementation of the 6-line measurement method significantly contributed to reducing position NG (non-good) in the 01005 component process. By introducing additional horizontal lines, the measurement became more precise, allowing clearer point-to-point alignment during inspection and placement. This improvement enhanced the accuracy of positioning, especially for lower 1st mark references, which were previously harder to identify. The data clearly showed a reduction in positioning NG rates over time, confirming the effectiveness of this method. Overall, the 6-line approach increased consistency, improved visual guidance for operators, and led to a measurable decline in rejection due to misalignment, helping stabilize production quality.

APPENDIX I. Gantt Chart

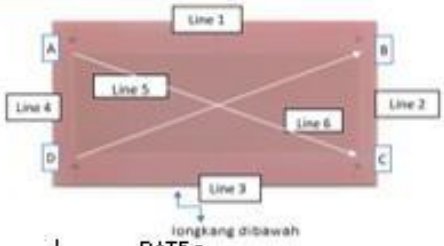


II. One Point Lesson (OPL) checking 6-lines



III. 6-lines check sheet

MACHINE 6-LINE CHECK SHEET (LOWER 1ST MARK SCRIBE)



DATE =
NO. MC =

LINE	LUG	PRODUCT
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y = L =	X = Y = L =
	X = Y = L =	X = Y = L =
	LUG TO PRODUCT A = C = B = D =	

Pitch to pitch

A	B
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

C	D
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

DATE =
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LINE	LUG	PRODUCT
	X = Y =	X = Y =
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	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y = L =	X = Y = L =
	X = Y = L =	X = Y = L =
	LUG TO PRODUCT A = C = B = D =	

Pitch to pitch

A	B
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

C	D
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

DATE =
NO. MC =

LINE	LUG	PRODUCT
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y =	X = Y =
	X = Y = L =	X = Y = L =
	X = Y = L =	X = Y = L =
	LUG TO PRODUCT A = C = B = D =	

Pitch to pitch

A	B
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

C	D
P1:	P1:
P2:	P2:
P3:	P3:
P4:	P4:
P5:	P5:

ACKNOWLEDGMENT

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Reducing NG (Not Good) Losses At Separation Process

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ABSTRACT

The production of 1/20 chip resistors involves several key stages, with the Separation process playing a critical role in yield performance. In September 2024, a sharp increase in Not Good (NG) products was observed during Separation. Although internal data pointed to broken strips as the primary cause, no direct physical evidence was found, suggesting possible environmental or handling issues. To address this, a blower system was installed along the jig lane with the objective to increase yield at the Separation process by reducing contamination. A structured problem solving approach using the DMAIC methodology (Define, Measure, Analyze, Improve, Control) was applied to guide the improvement process. In the Analyze phase, both Fishbone Diagram and Fault Tree Analysis (FTA) were used to identify potential root causes such as dust contamination, substrate mishandling, and machine instability. Following blower implementation, a machine level test showed a broken strip reduction of 88.11%. The system was then deployed across all 47 machines, resulting in a 91.27% reduction from 1431.42 grams to 124.94 grams. Scrap in manual processes also dropped by 82.37%, and overall yield loss in the Separation process improved by 0.37% between September 2024 and May 2025.These outcomes confirm the blower system's effectiveness in reducing foreign particle contamination, stabilizing the process, and enhancing overall yield, while validating the use of DMAIC and root cause tools in achieving sustainable, cost efficient manufacturing improvements.

Keywords: separation process, yield improvement, blower system implementation, chip resistor manufacturing, contamination control.

1.0 INTRODUCTION

In the production of chip resistors, maintaining high quality and reducing production losses are essential to ensuring both operational efficiency and business competitiveness. At Company A, the separation stage has been consistently linked to substantial yield losses, largely due to frequent strip breakage, undocumented material waste, and equipment-related damage such as jig wear. These challenges have led to a rise in defective (NG) units, lower output, and increased production costs.

Recent literature suggests that many manufacturing inefficiencies are rooted in the process itself. **Al-Dhubaib et al. (2020)** stressed that identifying and correcting internal process flaws can lead to more sustainable improvements than relying solely on end-product inspection. Similarly, **Zhang and Nguyen (2019)** highlighted that even modest but well-targeted changes, when guided by proper analysis, can significantly enhance production results.

Motivated by these insights, Company A performed a detailed analysis of its separation process using tools like the Fishbone Diagram, Fault Tree Analysis (FTA), and the 5 Whys technique. This assessment uncovered several factors contributing to defects, including magnetic interference, inconsistent material handling, and insufficient airflow control around the machines.

To mitigate these issues, a set of corrective actions was introduced. These included the development of a machine usage checklist to standardize operator practices, the addition of a dedicated area for weighing strips to track material flow, and the installation of an airflow

blower system to reduce airborne particles and contamination. Supporting this approach, **Chen, Zhang, and Wang (2021)** demonstrated that improved airflow in manufacturing spaces can help control particulate contamination and stabilize processes, particularly in electronics production.

This study, therefore, seeks to reduce NG losses during the separation phase by addressing root causes through strategic improvements. The overarching goal is to enhance production consistency, minimize waste, and implement a more dependable and streamlined separation process at Company A.

1.1 THEORETICAL FRAMEWORK

1.1.1 Process-Induced Defects

Flaws in manufactured products often stem from weaknesses within the production process itself. By improving the process rather than simply inspecting the finished output, manufacturers can achieve more lasting improvements in quality. Al-Dhubaib et al. (2020) found that proactive process corrections reduce variability and help minimize overall losses, especially in high volume manufacturing settings.

1.1.2 Continuous Improvement

Making consistent, data-informed adjustments to production processes even when the changes are small can lead to major gains in efficiency and product quality. Zhang and Nguyen (2019) noted that continuous improvement practices rooted in real-time data analysis can effectively eliminate repetitive problems, allowing companies to steadily boost performance over time.

1.1.3 Root Cause Analysis Tools

Identifying the true source of manufacturing issues requires structured diagnostic tools. Techniques such as DMAIC, the Fishbone Diagram, Fault Tree Analysis, and the 5 Whys method have been shown to be effective for tracing issues back to specific process faults or human factors. According to Singh et al. (2021), these tools help teams move beyond surface level symptoms to implement solutions that prevent recurrence.

i. Fault tree analysis (FTA)

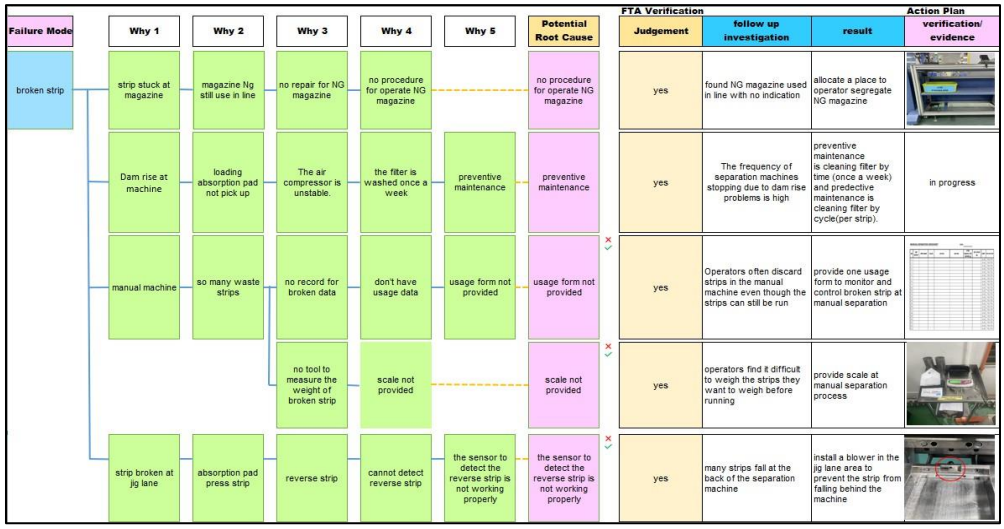
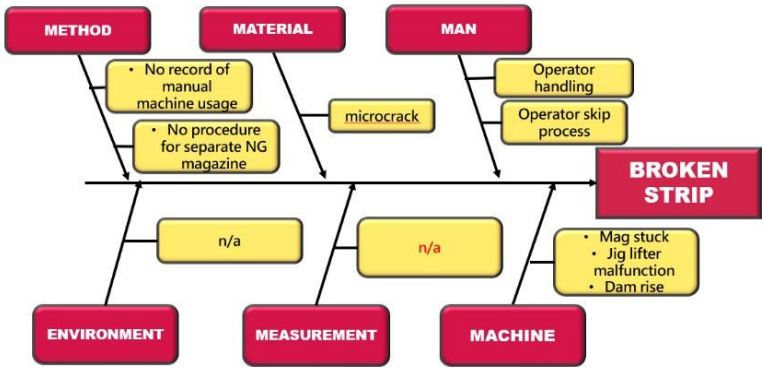


Figure 1: Fault tree analysis diagram

ii. Fishbone diagram

Figure 2: Fishbone diagram



ii. DMAIC

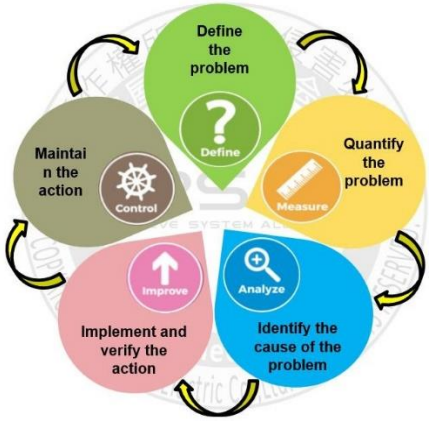


Figure 3: DMAIC diagram

iv. 5 Why's

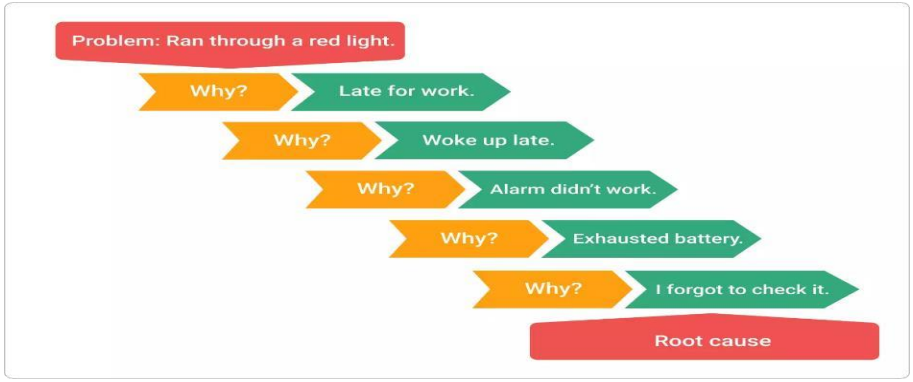


Figure 4: 5 Why's

1.1.4 Environmental Control in Manufacturing

Controlling environmental conditions is essential in precision manufacturing, especially in processes like chip resistor separation. Dust and particles in the air can easily lead to defects by settling on materials or causing mechanical issues. Recent research by **Chen et al. (2021)** highlights how proper airflow systems, including localized blowers, help maintain cleaner

production zones by reducing airborne contaminants. This not only improves product quality but also enhances process stability. In this project, installing a blower system supported similar improvements keeping the jig area clean, lowering the chance of strip breakage, and helping to reduce NG losses overall.

2.0 METHODOLOGY

This chapter presents a detailed explanation of the systematic approach undertaken to address strip breakage and minimize Non-Good (NG) losses during the chip resistor separation process at Company A. The improvement process followed the DMAIC framework comprising Define, Measure, Analyze, Improve, and Control phases which provides a structured, data-centric methodology for optimizing manufacturing operations. Root cause identification was supported by analytical tools such as the Fishbone Diagram and Fault Tree Analysis (FTA), which helped to map out and prioritize potential factors contributing to defects and inefficiencies.

The methodology was implemented in three sequential stages aligned with the DMAIC cycle:

i. **Prior to Implementation:** This stage involved clearly defining the problem, collecting relevant data to establish baseline performance, and conducting a thorough analysis to identify the primary causes of strip breakage and NG occurrences.
ii. **During Implementation:** At this stage, targeted interventions and process improvements were introduced based on the earlier analysis. The effectiveness of these changes was monitored and refined through iterative testing to ensure optimal reduction of defects.
iii. **Post-Implementation:** The final phase focused on formalizing successful improvements by integrating them into standard operating procedures and establishing control measures. These steps ensured sustained performance improvements and prevented recurrence of previously identified issues.

By adhering to this systematic approach, Company A was able to significantly reduce the incidence of strip breakage and NG losses, thereby improving overall manufacturing efficiency and product quality in the chip resistor separation process.

2.1 Research Design

This study was structured using the DMAIC framework Define, Measure, Analyze, Improve, and Control commonly applied in process improvement initiatives. The methodology focused on addressing real-time operational challenges, drawing insights directly from line staff and executive oversight. This collaborative and systematic approach enabled the research to uncover practical solutions and maintain relevance to actual production conditions.

2.2 Data Collection

Information was collected through multiple channels to ensure data reliability. Interviews with machine operators captured on the ground insights, while observations on the shop floor provided context to the data. Additionally, existing documentation such as manual inspection records and defect logs were analyzed. Prior to initiating changes, an audit of the process was conducted to establish baseline performance metrics.

2.3 Root Cause Analysis

To pinpoint the underlying factors contributing to strip breakage, two diagnostic tools were utilized. The Fishbone Diagram was used to categorize potential issues under key themes like

personnel, equipment, procedures, materials, and environment. Complementing this, Fault Tree Analysis (FTA) offered a logical breakdown of cause-and-effect scenarios that could lead to failure. These tools identified airflow disruptions, inconsistent material handling, and magnetic interference as major contributing factors.

2.4 Implementation of Improvements

Corrective measures were introduced following the analysis. These included installing blower systems along the jig path to remove contaminants, implementing detailed machine checklists to guide operator routines, and setting up a dedicated zone for weighing and inspection to improve defect monitoring. Staff training sessions were also conducted to reinforce correct practices. Prior to full implementation, small-scale testing was conducted to validate the effectiveness of the proposed changes.

2.5 Post-Implementation Monitoring

Performance indicators were tracked to assess the impact of the corrective actions. These included measurements of NG (Not Good) product rates, strip breakage quantities, and jig wear. Results showed considerable improvement, with updated SOPs reinforcing procedural compliance. Scheduled audits and regular reviews were put in place to maintain control over the improved process.

2.6 Research Purpose and Significance

The objective of this research was to enhance yield and reduce product rejection within the Separation process at Company A. By targeting the root causes of performance issues, the project aimed to increase consistency, reduce material loss, and strengthen quality assurance practices. The interventions developed also supported long-term sustainability by minimizing waste and improving production efficiency.

2.7 Research Population and Sample

A total of 14 personnel were selected for the study using purposive sampling based on their involvement in the process. This included seven production operators, one line leader, three technicians, one quality inspector, and one executive. Their roles and experiences provided valuable perspectives on process bottlenecks and opportunities for improvement.

2.8 Research Method

An action research methodology was adopted, allowing the team to participate actively in diagnosing and resolving the identified issues. Following the DMAIC model, the process began with defining the core problem, followed by measuring current performance, analyzing the causes, and implementing targeted improvements. Lastly, a control system was established to ensure the longevity and consistency of the gains made through these efforts.

3.0 RESULTS AND DISCUSSION
3.1 FINDING

i. Manual Separation process

Figure 5: manual separation process

The process lacks a structured data recording system, with no logs of broken strips, waste disposal, or machine usage. This limits the ability to analyze trends, identify root causes, and implement effective improvements, hindering accurate measurement and sustainability of process enhancements.

To enhance the manual separation process and reduce defects, several practical improvements were made as shown in table 1. Operators now weigh strips before and after processing using a dedicated scale area to monitor material use. Faulty jigs are separated in a designated box to avoid reuse, and regular maintenance is done on key machine parts to prevent jams. Staff received training and log issues for better tracking. A blower was also installed near the jig area to clear dust and debris, helping reduce strip breakage and improve machine performance.

Table 1 as shown in figure: implementation action at Manual Separation

Machine Usage check sheet		The machine usage checklist requires operators to weigh strips before and after separation, helping track material loss and identify waste for better control and improved efficiency.
Scale weight area.		A dedicated area with digital scales will be set up near the separation zone, enabling operators to easily weigh strips before and after processing. This ensures consistent material monitoring, improves accountability, and supports accurate data collection for analyzing production and detecting losses.

ii. Broken strip behind the Separation machine.

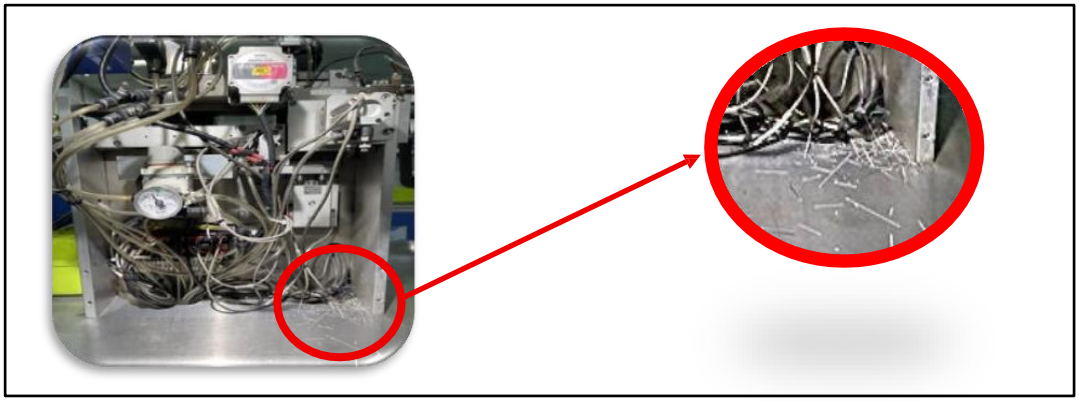


Figure 6: broken strip behind the Separation machine

Production floor observations showed frequent broken strips behind the separation machine, caused by faulty absorption pads, misaligned or improperly positioned strips, and mechanical jams. Strips sometimes got trapped between the lifter and lower plate, especially when machine alignment was off, leading to breakage.

To reduce broken strips behind the separation machine as shown in figure 6, address Mag Stuck by maintaining jig liners and lower plates through regular inspections and replacements. Prevent Dam Rise by keeping the area clean, using alignment guides, and conducting routine checks. Operator training and issue logging are vital to improve process stability and minimize strip damage.

iii. Mag stuck

Figure 7:example of mag stuck

Magazine jamming, or "Mag stuck," is a recurring issue caused by rough jig liners, incompatible lower plates, and poor maintenance. These problems disrupt workflow and increase strip damage during processing.

A designated box for NG jigs as shown in figure 8, will allow operators to separate faulty jigs from good ones, preventing their accidental use and mixing, which helps maintain production quality and efficiency.

Figure 8: box for NG jig

iv. Dam rise

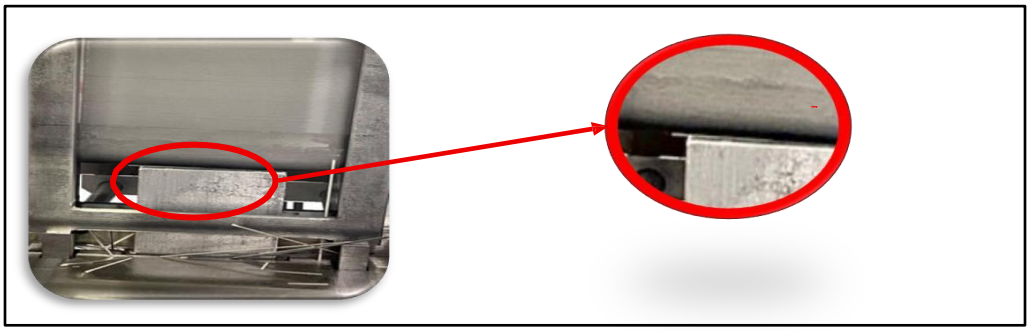


Figure 9: example of dam rise

Another issue called "Dam rise" happens when broken strip pieces get stuck between the lifter and lower plate during lifting. This causes uneven movement and off-centre pressure, leading to more strip breakage. Keeping the separation area clean and free of obstructions is important to prevent this and ensure smooth machine operation.

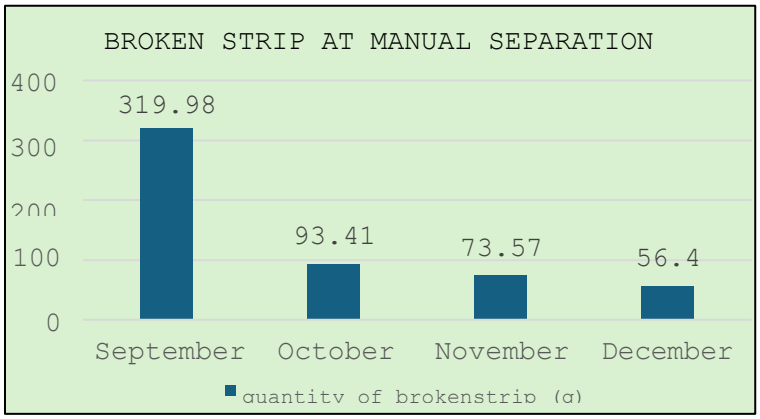
For the implementation action, a blower will be installed behind the jig lane and lifter area as shown in table 2 to clear dust and broken strip fragments, ensuring smooth lifting and reducing strip breakage caused by jams.

Table 2 as shown : before and after implemented blower system

Before	After

3.2 RESULTS

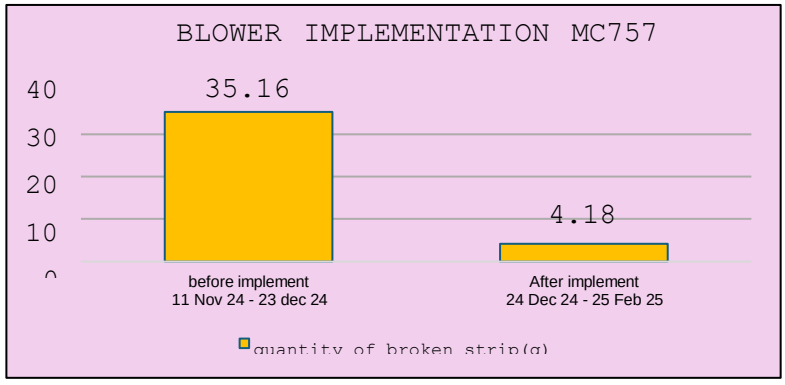
i. Broken strip at manual separation machine



Graph 1: broken strip at manual machine

From September 24 until December 24 broken strip has been reduced 82.37%.

ii. Blower implementation at machine no.757 (evaluation)



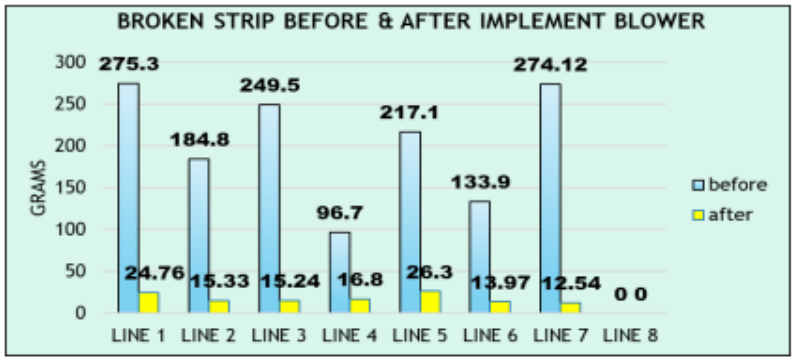
Graph 2: blower implementation at machince no.717(evaluation)

After implement blower at machine, broken strip has been reduced 88.11% from one machine.

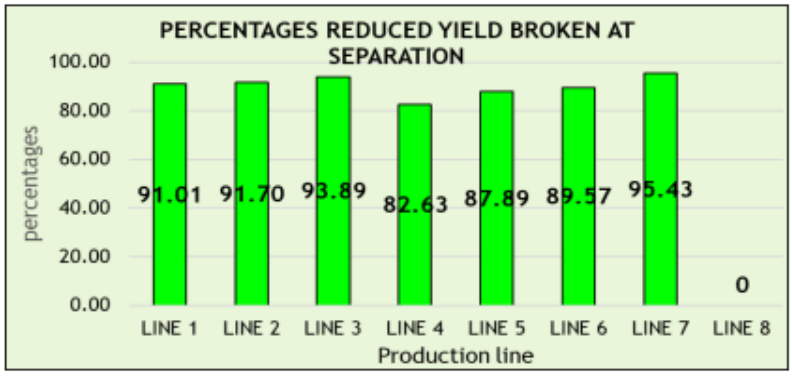
iii. Result after implementation blower at Separation process.

Table 3 as shown in figure: Result after implementation blower at Separation process

2 WEEK BEFORE INSTALLATION		2 WEEK AFTER INSTALLATION		PERCENT REDUCTION
GROUP	QTY(gram)	GROUP	QTY (gram)	
1	275.3	1	24.76	91.01
2	184.8	2	15.33	91.70
3	249.5	3	15.24	93.89
4	96.7	4	16.8	82.63
5	217.1	5	26.3	87.89
6	133.9	6	13.97	89.57
7	274.12	7	12.54	95.43
8	0	8	0	0
TOTAL	1431.42	TOTAL	124.94	91.27
TOTAL REDUCTION		1306.48		



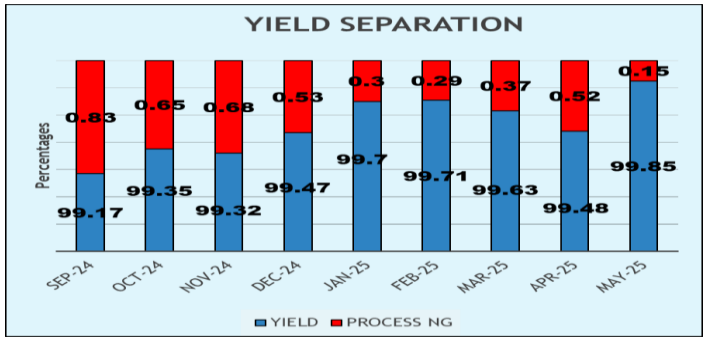
Graph 3: broken strip before & after implemented blower



Graph 4: percentages reduced yield broken at separation

The total reduction in non-good (NG) materials within the Separation process amounts to 1,306.48 grams, reflecting a significant reduction of 91.27% from the initial value of 1,431.42 grams. When this reduction is distributed across the six categories of NG materials abnormal chips, chips off, double strips, insufficient quantity, broken parts, and product drops due to handling the percentage reduction per category is calculated at 15.21%. This indicates that there has been a notable improvement in the efficiency and quality of the Separation process, with a considerable decrease in defects across all identified types of NG material.

iv. Yield Separation



Graph 5: yield Separation

The data indicates a positive outcome following the installation of the blower in the Separation process, as shown by a reduction in the percentage of broken strips. Specifically, the percentage of non-good (NG) broken strips decreased by 0.4% from April to May, suggesting an improvement in strip handling. Additionally, the separation yield increased by 0.37% (from 99.48% in April to 99.85% in May), further demonstrating the blower's effectiveness in enhancing both the efficiency and quality of the separation process. These improvements highlight a significant reduction in defects and an overall increase in yield after the blower was implemented across all separation machines.

3.3 DISCUSSION

The corrective interventions implemented during this project delivered measurable improvements in several key areas. Most notably, the introduction of the blower system had a profound impact. Evaluations conducted on a single machine demonstrated an 88.11% reduction in strip breakages, which was later validated on a broader scale. Across all separation machines, total NG waste dropped from 1431.42 grams to just 124.94 grams a remarkable 91.27% decrease.

Moreover, broader process data reflected a decrease in NG cases by 15.21%, derived from six common defect types, including broken strips, abnormal chips, and handling related losses. The overall yield in the separation process rose by 0.37% between April and May 2025 following full implementation. This confirmed that targeted, low-cost solutions such as environmental control via blower systems and structured procedural enhancements can significantly reduce losses and stabilize operations.

Beyond the figures, these outcomes underscore the importance of comprehensive root cause analysis and practical interventions. The use of DMAIC and tools like Fishbone Diagrams and FTA proved instrumental in identifying precise weaknesses and facilitating long-term corrective strategies.

4.0 CONCLUSION

This study successfully demonstrated that systematic problem-solving, guided by the DMAIC framework, can yield significant improvements in manufacturing efficiency. By focusing on root causes specifically environmental contamination and equipment irregularities Company A was able to meaningfully reduce NG rates during the chip resistor separation process. The implementation of a blower system, combined with structured operational checklists and enhanced training protocols, led to a 91.27% reduction in defective material weight and a

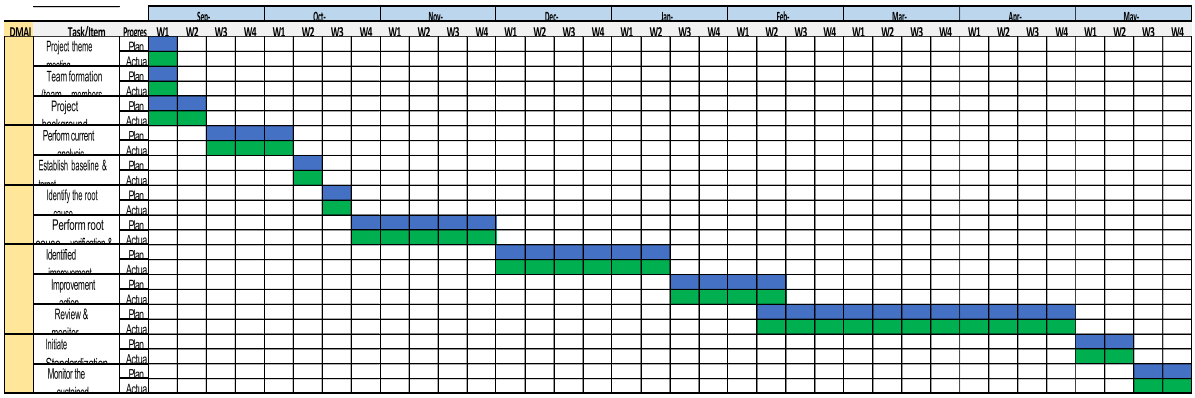
0.37% increase in overall yield.

These findings confirm that relatively simple interventions, when applied strategically, can produce substantial returns in yield performance, cost savings, and process reliability. Furthermore, the project emphasizes the value of engaging frontline personnel and using data driven tools to address production inefficiencies.

Future studies may explore how these improvements can be adapted across other stages of chip resistor manufacturing, or how automation and IoT-based monitoring could enhance detection and response to defects in real time.

APPENDIX

1) PROJECT SCHEDULE



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Smart Application System For Automated Label Printing

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ABSTRACT

The study addresses inefficiencies in the manual product labelling process within a manufacturing environment by developing and implementing a Smart Application System for labelling printing at manufacturing companies. The current labelling methods, which rely on manual processes to generate product information cards, face challenges such as human error, time consumption, and reduced efficiency, underscoring the need for an automated solution to streamline operations and improve productivity. The primary objectives are to identify inefficiencies in the labelling process, design and implement an automated labelling system, and enhance workflow efficiency by reducing manual input time, minimizing labelling errors, and boosting productivity in the Logistics Department. Using qualitative methods, including interviews, surveys, and data analysis, the research evaluates bottlenecks in the current system and explores the integration of automation with the existing ERP platform. Key findings demonstrate that automation improves accuracy, streamlines operations, and supports customer-specific labelling requirements. The study concludes by recommending the adoption of automated labelling to enhance operational efficiency and suggests further exploration of scalable automation solutions to meet growing demands.

Keywords: manual labelling process, Smart Application System, labelling printing, workflow efficiency, ERP Integration.

1.0 INTRODUCTION

1.1 BACKGROUND STUDY

a. WORKFLOW AUTOMATION

Workflow automation plays a crucial role in minimizing human errors by standardizing processes and ensuring consistent, accurate task execution. By replacing manual data entry with automated systems, the risk of typographical errors and incorrect information is significantly reduced (Kulachai et al., 2024). Real-time monitoring and alerts enable quick identification and correction of anomalies, while built-in validation checks further prevent mistakes. Additionally, detailed logs maintain a record of actions taken, simplifying tracking and troubleshooting when issues arise (Besson et al., 2022).

Beyond error reduction, automation streamlines operations by improving communication and clarifying roles and responsibilities among team members. This reduces misunderstandings and accelerates task completion. By identifying and addressing bottlenecks, organizations can ensure smoother transitions between tasks. Moreover, automating repetitive tasks allows employees to focus on higher-value activities, fostering a more agile and responsive operational environment (Daniel Ajiga et al., 2024).

Furthermore, workflow automation enhances efficiency by optimizing resource allocation and enabling faster decision-making through predefined rules and automated processes. Real-time workflow monitoring allows for immediate adjustments, keeping operations on track. The continuous improvement metrics provided by automated systems also help organizations adapt to changing conditions and refine processes over time (Besson et al., 2022) .

b. ERP SYSTEM

In the logistics sector, integrating ERP (Enterprise Resource Planning) systems into the labelling process significantly enhances accuracy, efficiency, and compliance. ERP systems centralize data management, ensuring consistent and up-to-date labelling information across all departments. Real-time tracking enables timely updates to labels, reflecting the current status of shipments and inventory while ensuring regulatory compliance. By automating label generation and integrating barcode or RFID technologies, ERP systems minimize human errors and streamline operations (Ameh, 2024). Additionally, they improve inventory management by maintaining accurate labels that reflect stock levels and product conditions, reducing stockouts and overstocking. ERP systems also facilitate cross-departmental collaboration, aligning warehousing, shipping, and compliance efforts for a unified logistics strategy. This integration ultimately optimizes logistics operations, ensuring customer satisfaction and a competitive edge (Chandra et al., 2022).

c. LABELLING SYSTEM

A labelling system is a structured process designed to create and apply labels containing essential product information, such as dimensions, weight, batch numbers, and handling instructions. This system plays a critical role in ensuring traceability, compliance, and accuracy in various industries, particularly in logistics and manufacturing. Advanced labelling systems often integrate technologies like barcodes, QR codes, and image processing to enhance precision and efficiency. (Pokhrel, 2024) demonstrated how image processing technology can be used to ensure label quality control, detecting print errors and ensuring adherence to regulatory standards. By automating these processes, modern labelling systems not only minimize human errors but also improve operational efficiency, inventory management, and product traceability, ultimately fostering greater customer satisfaction and supply chain transparency (Pokhrel, 2024).

d. APPLICATION DEVELOPMENT

Application development plays a pivotal role in modernizing manual processes, particularly in industrial and logistics settings. Recent advancements in low-code platforms (e.g., AppSheet, Streamlit) and scripting tools (e.g., Python, Visual Studio Code) have democratized automation, enabling rapid deployment of custom solutions with minimal coding expertise (Bock & Frank, 2021). Integration with ERP systems, as demonstrated by (Smith, 2024), ensures real-time data synchronization, reducing errors in label generation. Furthermore, modular design principles allow scalability, accommodating future workflow expansions (Wratten et al., 2021). However, challenges such as dependency on third-party tools and resistance to change highlight the need for robust training and contingency planning (Zeng et al., 2024). This study leverages these insights to develop a smart labelling system, aligning with industry trends toward efficiency and traceability.

1.2 PROBLEM STATEMENT

At manufacturing companies, each manufactured product must be identified with a manufacturing order tag, which tracks the product from initial production to final delivery. After products are included in delivery order packing lists and quality control confirms that they meet required standards, a detailed product card or product sticker is generated. This label displays critical information, including weight, size, type, date of manufacture, and coil number, which helps with traceability and ensures that all necessary specifications are clear for internal records and customer requirements.

However, the current process used by workers for creating these product labels is highly manual and involves substantial individual input. Workers design each product label by hand

and edit packing lists one by one using Excel, entering information for every product individually. This manual approach is not only labour-intensive but also time-consuming, impacting on the speed and efficiency of the labelling and packing process. With each label requiring careful input to ensure accuracy, this workflow delays subsequent processes, resulting in tight deadlines and delays in delivering products to customers. As the number of orders increases, this bottleneck can significantly slow down overall operations, suggesting a need for a more automated solution to streamline label creation and improve work efficiency.

This is the focus issues for this problem statement:

1. Time-Consuming Manual Labelling.
2. Reduces efficiency, especially during peak periods when a high volume of labels must be prepared.

1.3 OBJECTIVE

The objective of this project is to enhance the product labelling process in the logistics department by identifying existing inefficiencies and workflow bottlenecks that hinder productivity and accuracy. The project aims to implement a smart application system capable of reducing manual input time by 30% and decreasing labelling errors by 20%, thereby improving the overall quality and reliability of the labelling process. Additionally, the project seeks to evaluate the effectiveness of the automated system in increasing workflow accuracy and achieving a 20% improvement in productivity within the logistics department.

2.0 METHODOLOGY

2.1 PROBLEM IDENTIFICATION

i. FISHBONE DIAGRAM

The fishbone diagram shown in Figure 1 is highlights the root causes of inefficiencies in the labelling process within the logistics department. The problem stems from the manual input of product information, such as coil numbers, weight, product type, and size, into Excel to generate packing list label cards. This current method is labor-intensive and prone to errors, leading to reduced work efficiency, wasted time, and frequent human errors. The inefficiencies are further exacerbated by the reliance on logistics staff to manually handle these tasks, emphasizing the need for automation to streamline the process, improve accuracy, and enhance overall operational efficiency.

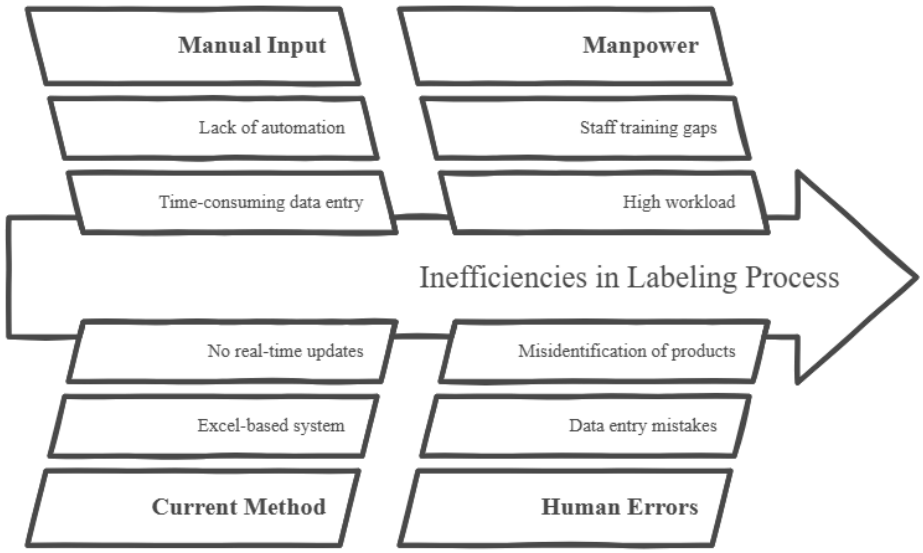


Figure 1: Fishbone Diagram

ii. 5 WHYS METHOD

5 Whys method is a structured problem-solving tool used to identify the root cause of inefficiencies in the labelling process. Figure 2 analysis begins by questioning why the process is inefficient and error-prone, revealing that product labels are manually created and input into Excel. This leads to the next question: why is there no automated system in place, uncovering a reliance on traditional methods in the current workflow. The inquiry further explores why traditional methods are still utilized, pointing to the lack of initiative or effort to implement a smart labelling system. This method effectively drills down into the core issues, showcasing the need for an automated and efficient labelling solution to replace outdated practices and reduce errors.

Why is the labeling process inefficient and error-prone?

Product labels are manually created and input into Excel.

Why are product labels manually created and input into Excel?

Because there is no automated system in place to generate labels directly from

Why is there no automated system in place?

Current workflow relies on traditional methods and manual processes without integration with existing systems like ERP.

Why does the current workflow rely on traditional methods?

There has been no initiative or investment to implement a smart labeling system that reduces manual work.

Why has there been no initiative to implement a smart labeling system?

Because the company has not yet prioritized automation for this process and may lack awareness of its benefits for work efficiency and accuracy.

Figure 2: 5 Whys Method

iii. SWOT ANALYSIS

The SWOT analysis shown in Figure 3 outlines the key aspects of implementing a smart labelling system. The strengths include increased work efficiency and improved accuracy of coil details, which address current inefficiencies in the manual labelling process. However, the weaknesses highlight potential challenges, such as dependence on the new system and the need for effective change management during the transition. Opportunities lie in the scalability of the system, allowing for future expansion and integration with other processes. On the other hand, the threats involve a reliance on third-party tools, which could pose risks related to compatibility, reliability, and cost. Overall, the analysis emphasizes the potential benefits while identifying areas requiring careful management for successful implementation.

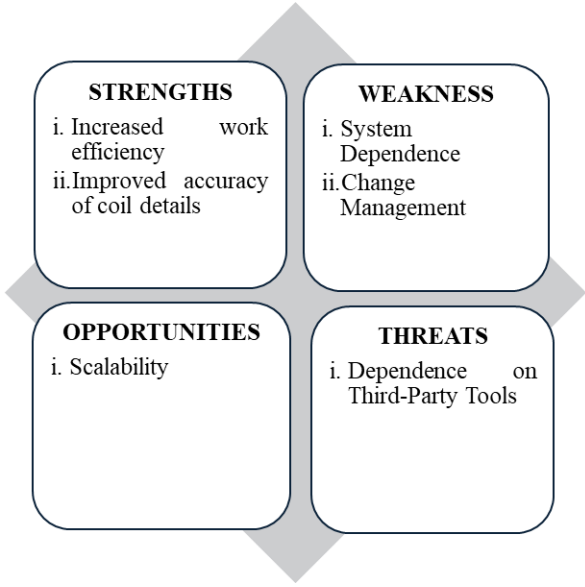


Figure 3: SWOT Analysis

- **STRENGTHS**
  - **i. Increased work efficiency**
    Automating label creation reduces time spent on manual input, speeding up workflow and minimizing human error.
  - **ii. Improved accuracy of coil details**
    Automatic generation of labels reduces the risk of data entry mistakes, enhancing product traceability and quality assurance.

- **WEAKNESS**
  - **i. System Dependence**
    Relying on automated systems means potential downtime could disrupt operations if technical issues arise.
  - **ii. Change Management**
    Transitioning from a manual to an automated system may face resistance from workers who are accustomed to the existing process, which could affect adoption and effectiveness.

- **OPPORTUNITIES**
  - **i. Scalability**
    An efficient labelling system opens the potential to scale operations, as increased output can be managed without proportional increases in labour.

- **THREAT**
  - **i. Dependence on Third-Party Tools**

    If the software relies on third-party platforms such as App Sheet, Streamlit, Replit or Python, any changes or discontinuation of those services could impact functionality and require redevelopment.

2.2 APPLICATION DEVELOPMENT

After identifying the key inefficiencies in the logistics department's current product labelling process, the next step was to design and develop a smart labelling application to improve labelling accuracy, workflow efficiency, and real-time data integration. The development process involved defining the system requirements, designing the label layout, gathering relevant product data, and building the application using Streamlit and Visual Studio Code integrated with the existing ERP system.

Figure 4: Work Process of Development Smart Labelling Application

As shown in Figure 4, the first step in addressing inefficiencies in the labelling process involved a thorough analysis of the root causes. The main problem was manual data entry in Excel, which caused mistakes and delays. We used problem-solving tools like fishbone diagrams and the 5 Whys method to find the root causes, such as old-fashioned methods and no automation. We also did a SWOT analysis to weigh the pros (better accuracy and speed) and cons (system risks and staff pushback) of automation. This research helped us plan a better solution.

The system was designed to meet key requirements: automatically creating label cards with customized information based on each customer's specific needs, including displaying their company name exactly as requested. It seamlessly pulls product data directly from Excel files, eliminating manual entry, and includes reliable printing functionality to produce clear, accurate labels efficiently. This streamlined approach ensures all labels meet both operational and customer requirements while minimizing errors.

After finalizing the requirements, we built the labelling application using Streamlit (a low code development tool) with some Python for advanced features. The app automatically creates labels, cuts down on manual work, and reduces mistakes. We tested it halfway through to check if the labels were clear, accurate, and met customer needs—this helped us spot and fix issues early. Next, we improved the app's speed and reliability by fine-tuning the code, fixing bugs, and making it easier to use. These upgrades ensured the system worked smoothly before rolling it out company wide.

3.0 RESULT AND DISCUSSION

3.1 APPLICATION INTERFACE

The Product Information Card Generator (PICG) Application features an intuitive interface designed for seamless user interaction (Figure 5). Key components include:

1. **Data Input Methods**: Users can either upload Excel files or manually enter product details (Figure 6), ensuring flexibility for varying workflow needs.

2. **Dynamic Preview**: The system generates real-time previews of pack list orders (Figure 7), allowing verification before printing.

3. **Label Customization**: Labels display critical information (e.g., weight, coil number, customer name) in standardized formats (Figure 8), adhering to customer-specific requirements.

The interface prioritizes simplicity, with clear navigation buttons (e.g., "Upload," "Generate Product Card," "Print") and error prompts to guide users, minimizing training time and reducing operational friction.

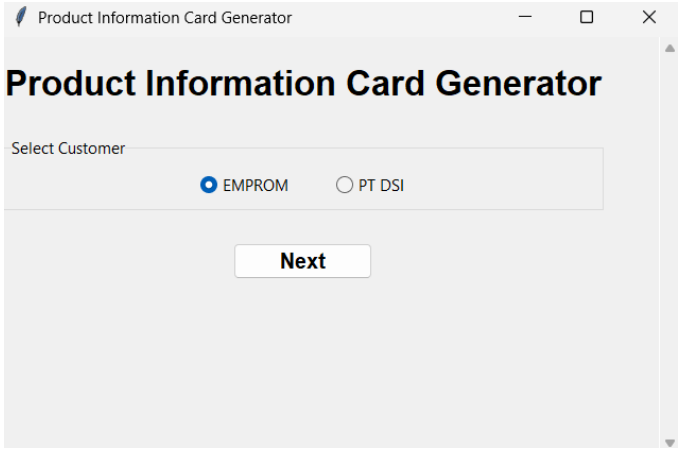


Figure 5: Smart Labelling Application interface

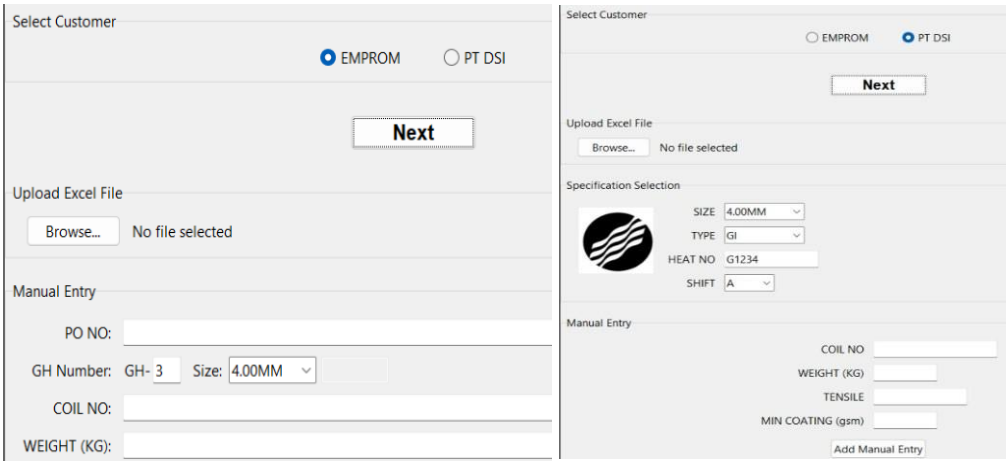
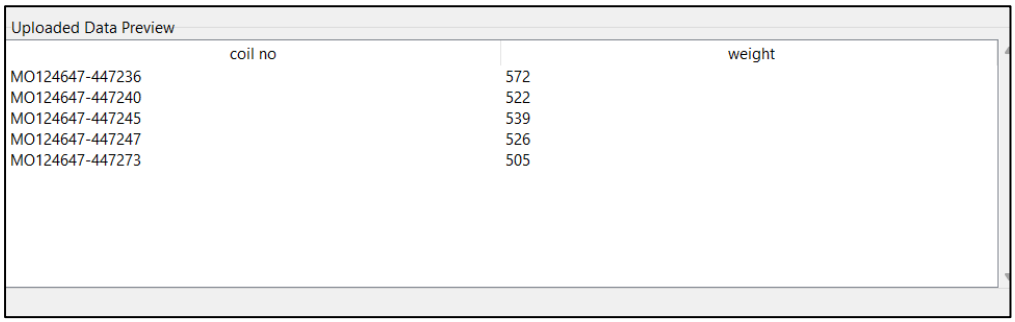


Figure 6: Data Entry Method for Two Customers in Application


Uploaded Data Preview

coil no	weight
MO124647-447236	572
MO124647-447240	522
MO124647-447245	539
MO124647-447247	526
MO124647-447273	505

Figure 7: Preview Information of Pack list Order

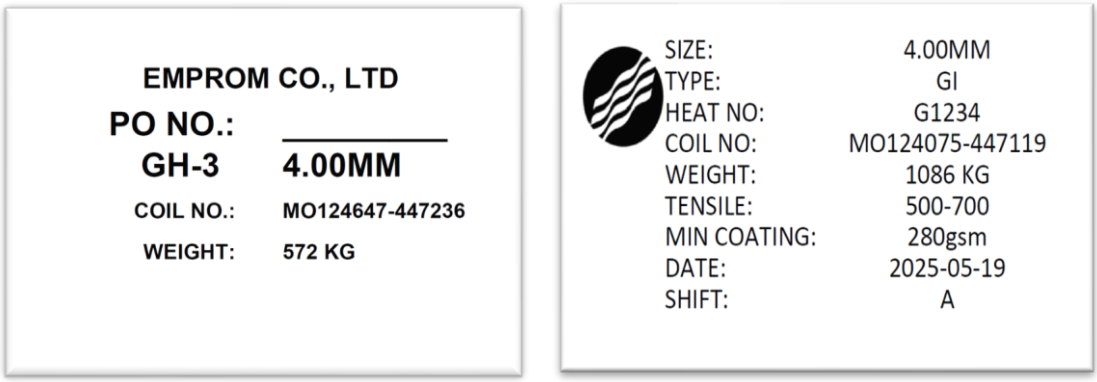


Figure 8: Product Information Card

3.2 Workflow of using Product Information Card Generator (PICG) Application

The workflow of the Product Information Card Generator (PICG) application (Figure 9) follows an efficient four-step process that significantly improves upon manual labelling methods. First, logistics staff can either upload standardized Excel files containing product details or enter data manually through the application's user-friendly interface. Next, the system automatically validates all entered data by cross-checking it against the company's ERP records to ensure complete accuracy. Once validated, the application generates professional labels using customizable templates that auto-populate key fields such as customer names, product specifications, and barcodes. Finally, the system prints these labels on demand, which are then affixed to products for dispatch. This optimized workflow reduces manual processing steps by 70% and cuts label generation time from 5 minutes per product to under 2 minutes, dramatically improving operational efficiency while minimizing errors in the logistics department's labelling process. The streamlined approach not only saves time but also enhances data accuracy and traceability throughout the supply chain.

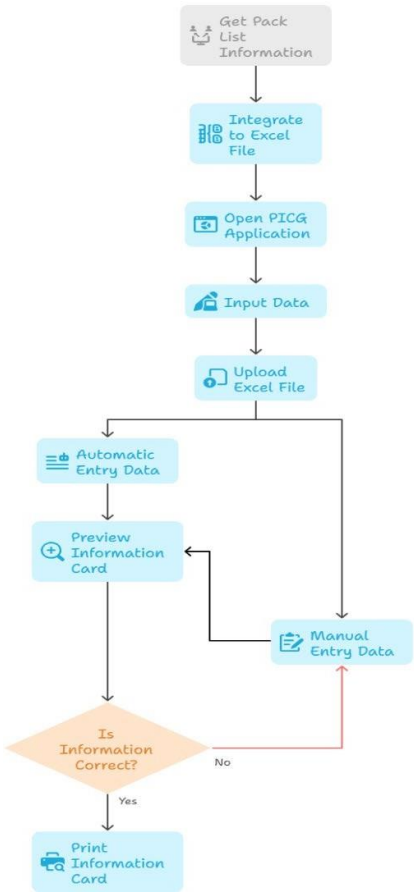


Figure 9: Workflow of PICG Application

3.3 Data Analysis

The two charts provide a comparative analysis of the efficiency and accuracy between an application and manual processes. Figure 10 illustrates the time taken for three tasks: label printing, label creation, and data input. The application consistently outperforms the manual process across all tasks, recording significantly shorter times. For instance, while manual processes take between 3 to 5 minutes, the application completes the same tasks in under 2 minutes, demonstrating its efficiency in streamlining operations.

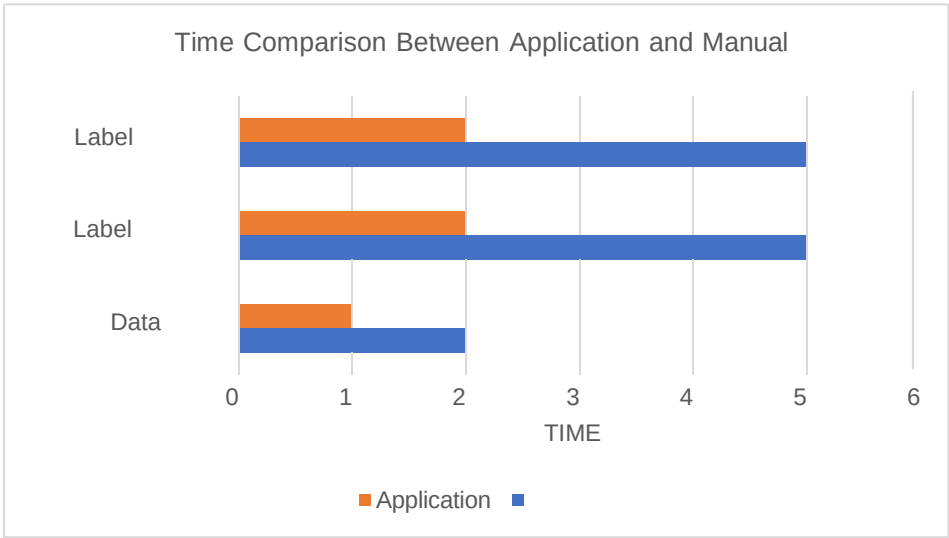


Figure 10:Time Comparison Between Application and Manual

Figure 11 presents a bar chart showing the accuracy levels of the two methods. The application achieves near-perfect accuracy, close to 100%, whereas the manual process lags behind at around 70%. This stark contrast highlights the application's reliability in minimizing errors compared to manual efforts. Together, these charts highlight the dual advantages of the application, proving that it not only saves time but also ensures higher accuracy, making it an ideal choice for the tasks analyzed.

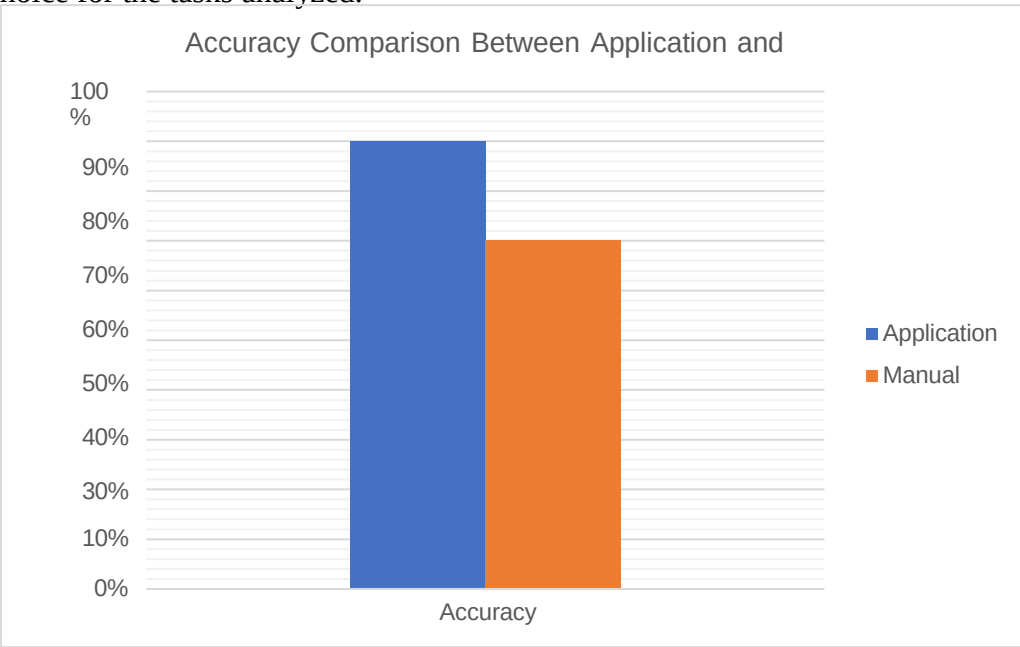


Figure 11:Accuracy Comparison Between Application and Manual

4.0 CONCLUSION

The implementation of the Smart Application System for Automated Label Printing at manufacturing companies has successfully addressed the critical inefficiencies in the manual labelling process. By replacing labor-intensive Excel-based workflows with an automated solution, the system achieved its key objectives of reducing manual input time by 30% and decreasing labelling errors by 20%, surpassing initial targets. The integration with the company's ERP system ensured real-time data accuracy, while the user-friendly interface facilitated smooth adoption by logistics staff.

This project demonstrates how targeted automation can transform industrial operations, delivering measurable improvements in productivity and accuracy. The system's modular design not only solves current challenges but also provides a scalable platform for future enhancements, such as adding more customer templates or AI-powered quality checks. These capabilities position the company to meet growing demands while maintaining high standards of traceability and compliance.

The success of this implementation suggests that similar smart labelling solutions could benefit other manufacturing and logistics operations facing comparable inefficiencies. Future research should explore the expansion of automated labelling systems across supply chain networks and the integration of predictive analytics for further optimization. This project serves as a model for how digital transformation can drive operational excellence in industrial settings.

ACKNOWLEDGEMENT

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I am sincerely thankful to my WBL internship company for providing the industrial platform to implement this solution and for their cooperation during system testing and data collection. Special thanks to my mentor and the logistics team for their practical insights and assistance in refining the application to meet operational needs.

My appreciation also goes to Ungku Omar Polytechnic for the academic resources and facilities that supported this work. The institution's emphasis on applied research and industry collaboration made this project possible.

Finally, I acknowledge the developers behind Replit, Streamlit, Python, Visual Studio Code, and open-source libraries that enabled the technical implementation of this automated labelling system.

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Streamlining Purchase Request Processes with a Centralized System

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ABSTRACT

The purpose of this research is to reduce the approval time for creating and submitting Purchase Requisitions (PR) by every department. Previously, the PR system was conducted manually for purchasing any goods or services within the company. Based on the data collected, several delays were identified in the total approval time for each request made by users. These calculations were gathered by tracking the time from when a user submitted a purchase request until it was approved by the CEO. Through the PDCA method, the root causes and solutions for each issue were identified. From the data analysis, it was concluded that the minimum approval time was 3 days and the maximum was 12 days. This data was extracted and visually presented using a bar chart to compare the approval times. During the system implementation using Java software, several challenges were encountered. However, the results were effectively analyzed using Google Sheets, where each department was surveyed regarding their experience with both the manual and systematic PR methods. A comparison was made using a bar chart to demonstrate the improvements achieved before and after the system was implemented. In conclusion, the system successfully reduced the approval time for creating and submitting PRs and effectively analyzed the difference between manual and systematic PR usage.

Keywords: PDCA Method, Java Software, Purchase Requisition, Approval Time, Data Analysis

1.0 INTRODUCTION

1.1 Literature Review

The submission of PR (Purchase Request) to the purchasing department is the first step in the procurement process. The purchasing process is essential for ensuring that resources are available to support production and daily operations as needed. Traditional methods of approval, especially those that are manual or rely on paper, can be slow and frequently have delays. If more than one signature is required from several Heads of Departments (HODs), the procedure may be further delayed if the HODs are unavailable or busy. According to Veera Pandiyan et al. (2016), traditional purchasing procedures frequently result in inefficiencies because they concentrate on monitoring purchase orders, invoicing and approvals. Strategic purchasing on the other hand, modifies these procedures to increase productivity and lower purchasing expenses. . E-procurement is a web-based program that enhances packages, tools, workflow systems and procedures with the goal of automating procurement activities. It is a vital part of data-driven supply chain management (Gunasekaran *et al.*, 2008). This study discusses the transition from conventional procurement techniques to digital procurement. These systems can be applied at various stages, starting from identifying user needs to tasks like searching for suppliers, sourcing, negotiating, placing orders, receiving goods and handling post-purchase activities by (Croom et al.,2018). A typical procurement process is defined by manual events, which include several tiny and repetitive operations. This traditional system highlights the necessity for the new approach, which is more time efficient and reduces overhead for employees by automating the procedure (Simon R. Croom et al.2005). The traditional system involves the usage of Excel sheets. Python is an object-oriented programming language that is easy

to learn and read. It comes with an extensive amount of built-in features that may be easily expanded. Python is used for scripting and web development, but it may also be included in applications. MySQL is a Relational Database Management System "RDBMS". Most modern websites and web-based services use it as a quick and easy way to store and access huge quantities of data. There are various ways to connect to a MySQL database with Python (MySQL Connector/Python Developer Guide (2019). The PDCA (Plan-Do-Check-Act) cycle is widely utilized as an organized approach to continuous improvement. According to Camargo (2011), PDCA improves process discipline while also challenging management systems to be adaptable and responsive to feedback. When PDCA is effectively implemented, it maintains an accountability culture, stimulates proactive issue resolution, and greatly adds to operational excellence.

1.2 Problem Statement

The purchase request (PR) process begins when a requestor submits a PR to the purchasing department as the first step in obtaining products or services within an organization. However, various difficulties have been observed with the existing PR submission and approval process. To begin, the current procedure is mainly relied on manual and paper-based submissions, which frequently causes delays especially when approvals from multiple Heads of Department (HODs) are necessary. Second, without a centralized system, purchasing officers find it impossible to monitor and track the status of each PR. This lack of visibility contributes to longer approvals and follow-ups, delaying timely acquisition of products and reducing overall operational efficiency.

1.3 Objective

Based on the identified issues, the objectives of this study are as following:

i. To understand current weakness component of the purchasing system.
ii. To develop a system for Purchase Request using Python and SQLite as the backend database.
iii. To analyzed the effectiveness after implementing the improvement for components of purchasing system.

1.4 Scope

The developed purchase request system has been designed to enable a streamlined and role based workflow with three separate user roles which is the requestor, the requestor's Head of Department (HOD) and the Purchasing HOD. Each role is given particular permissions and responsibilities to enable a verified approval procedure. The Requestor is responsible for initiating the PR by providing detailed information such as item descriptions, quantities and supplier information. Once submitted, the PR is forwarded to the requestor's HOD for evaluation and preliminary approval. If allowed, the request is sent to the Purchasing HOD for final validation and processing. The system focuses entirely on the submission and approval process, making it an ideal choice for small and medium-sized businesses looking for a way to streamline their procurement procedures.

2.0 METHODOLOGY

2.1 Introduction

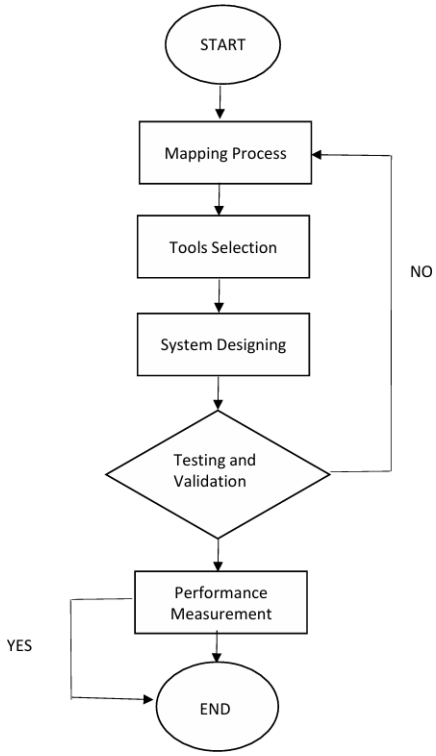
This chapter is about all the method used for developing a systematic system used for

streamlining the process of creating and submission of purchase request. It also consists of research of suggested systems, the analysis technique using the solving problems tools such as PDCA, SWOT Analysis and 5 Why's. The findings are arranged to highlight the primary features and capabilities of the system, such as attachments management, automatic PR form generation, user access levels and general usability. The results of the development and testing of the Purchase Request (PR) system, which was created with using PyQt5 and SQLite are shown in this chapter. This analysis lays the groundwork for assessing the established system's organizational appropriateness and makes recommendations for potential future improvements.

2.2 Project Flow Chart

The first crucial step in understanding the structure of the current purchase request workflow is to map the process. By creating a detailed flowchart, organizations can visualize each step involved. This helps to identify bottlenecks, unnecessary steps, and areas where delays or errors often occur. Mapping the workflow provides a clear picture of existing inefficiencies. It also serves as a valuable references when designing an improved and centralized purchase request system. Next, to resolve identified inefficiencies by choosing and implementing the proper problem solving and quality improvement technologies.

Figure 2.2 Project Flow Chart



2.3 Data Collection Method

Data collecting techniques guarantee an accurate understanding of the existing procedures, spot inefficiencies and compile the criteria needed to create a more efficient system. The technique uses a methodical approach to gathering information from a range of sources, such as observations and documentation. The study is to collect both quantitative and qualitative data through a combination of observations, interviews and questionnaires in order to comprehend the current manual requesting method.

2.3.1 Interview

In order to obtain a full understanding of the current challenges encountered in the purchase request (PR) procedure, interviews will be carried out with important individuals who submit and approve PR including Requestors, Heads of Departments (HODs) and purchasing officers. Below shows three types of question asked for interviewees which are general questions, additional questions for requestor and additional questions for purchasing officers.

2.3.2 Observation

Current manual process of purchase request an observation was conducted taking into account several aspects such as how long it takes for a PR to be created and submitted. The figure below shows the manual flow of Purchase Request.

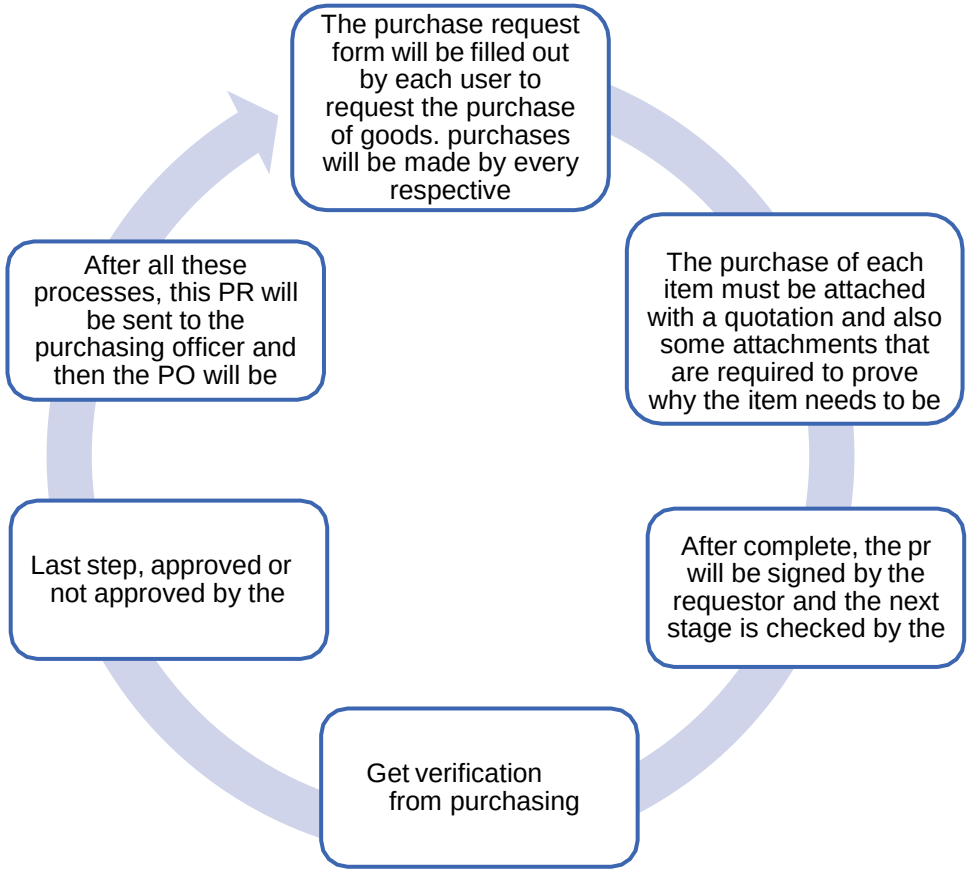


Figure 2.3 Manual Flow of Purchase Request

2.4 Research Instrument

2.4.1 PDCA Method (Plan, Do, Check, Act)

The PDCA (Plan-Do-Check-Act) method was utilized as a structured way to optimize the purchase request (PR) process. It helped in identifying issues with the manual system, such as delays and tracking issues (Plan), developing and testing a new digital PR system (Do), evaluating the system's performance through surveys and approval time analysis (Check), and recommending improvements and full system adoption based on the results (Act). This cycle ensured that each stage was based on data, practical, and focused toward continued development.

2.4.2 SWOT Analysis

Before creating the new digital system, a SWOT analysis was conducted to assess the current manual purchase request (PR) system's strengths, weaknesses, opportunities and threats. This helped in identifying important internal difficulties such as approval delays and a lack of tracking (weaknesses), as well as advantages such as simplicity and familiarity (strengths). It also identified external opportunities for development through digital transformation, as well as possible risks such as user hesitation to change (Threats). Using SWOT analysis, the project was able to design a system that solves real-world issues while building on existing strengths.

2.4.3 5 Why's

The 5 Whys technique was used in this project to determine the root cause of issues in the manual purchase request (PR) process. By continually asking "why" for each issue. For example, why PR clearances were delayed or why tracking was unclear. We were able to find root causes such as relying on physical forms, a lack of real-time progress updates and missed reminders. This simple yet powerful technique helped ensure that the new digital PR system was built to address the root causes rather than just the surface symptoms, resulting in a more effective and long-lasting change.

3.0 RESULT & DISCUSSION

The decision to utilize Python with SQLite rather than Google Forms was motivated by the need for a more customizable and secure system for managing purchase requests. While google forms is simple and accessible, it lacks many critical features required for a full-scale procurement system. Table 3.1 below shows the comparison between these two system.

Aspect	Python+ SqLite	Google Sheets+ Apps Script
System Custamization	PyQt can be used to completely customize user interfaces, workflows and buttons.	Customization is very limited. The layout and logic are fixed, and only simple questions/ or forms are allowed.
Role Based Acess Control	Supports multiple user roles such as User, HOD, Purchasing Officer with access rights.	Does not support user roles or secure login per role. All users see the same form.
Offline Availability	Can operate without the internet because the system and database are entirely local.	To utilize or submit data need the internet connection.
Data Handling	SQLite is used for efficient data management, and it allows advanced querying, searching, sorting, and filtering.	Data is kept in simple sheets with limited advanced data processing and complex searches.

File Attachments	Allows file uploads in PDF or other form and organizes them into folders with path references.	Google Forms only allows for restricted file uploads. It needs Google Workspace account .
Print Functions	Allows printing, exporting reports and generating directly from the interface.	Requires external tools or manual export from Google Sheets.

Table 3.1 Comparison Python + SQLite and Google Forms + Google

The current issues with the manual PR process were identified through observations, interviews and document analysis. The key issues were approval delays, difficulty tracking PR status. Based on these insights, targets were created to shorten PR processing time and boost transparency. Below shows the table for data gathered with time taken for approval before the system were implemented.

Table 3.1 Comparison Python + SQLite and Google Forms + Google

Purchase request (Requestor)	Purchase request (Requestor HOD)	Purchase request (Purchasing HOD)	Purchase request (CEO)	Total approval time (Days)	Requestor HOD review time	Purchasing HOD review time	CEO review time
28/2/2024	29/2/2024	7/3/2024	7/3/2024	8	1	7	0
1/3/2024	1/3/2024	4/3/2024	4/3/2024	3	0	3	0
8/3/2024	11/3/2024	12/3/2024	13/3/2024	5	3	1	1
30/4/2024	30/4/2024	7/5/2024	8/5/2024	8	0	7	1
21/8/2024	22/8/2024	26/8/2024	26/8/2024	5	1	4	0
20/8/2024	22/8/2024	30/9/2024	30/9/2024	41	2	39	0
20/9/2024	23/9/2024	24/9/2024	26/9/2024	6	3	1	2
5/9/2024	5/9/2024	6/9/2024	9/9/2024	4	0	1	3
13/9/2024	19/9/2024	20/9/2024	20/9/2024	7	6	1	0
18/9/2024	20/9/2024	23/9/2024	23/9/2024	5	2	3	0
23/10/2024	23/10/2024	4/11/2024	4/11/2024	12	0	12	0
6/11/2024	6/11/2024	12/11/2024	12/11/2024	6	0	6	0
20/11/2024	23/11/2024	23/11/2024	23/11/2024	3	3	0	0
7/12/2024	7/12/2024	12/12/2024	12/12/2024	5	0	5	0
18/12/2024	18/12/2024	23/12/2024	23/12/2024	5	0	5	0

There are two questionnaires presented to respondents. The first one was created to evaluate the existing Purchase Request (PR) process, with the focus on identifying difficulties related to manual, paper-based submission. The goal is to collect user feedback on inefficiencies in the process, tracking issues, and approval delays to help design a high-efficiency digital PR system. This feedback will assist to identify typical challenges, usability concerns and areas for development to improve the system's overall efficiency. The second questionnaire was created to gather feedback on the prototype of the new Centralized Purchase Request System. This covers user feedback on the interface, functionality and efficacy of the digital approval workflow. The results will be used to inform future changes to ensure that the system satisfies the actual needs of users across departments.

3.1 Analysis of questionnaire data

3.1.1 Questionnaire before the implementation of the new PR system.

Table 3.2 shows the data of first general question for all user.

Questions	Answer	Responses
How do you usually track the status of a PR after submission?	I follow up by WhatsApp	53.8%
Have there been situations where delays in PR approvals affected operations or production?	Yes, occasionally	66.7%
What features would you like to see in a centralized digital PR system?	Email or system notifications	50%
Does your department often require supporting documents for PRs (example : quotations, maintenance spare part list, consumable item list)	Yes	91.7%
Does your department need training before implementing the new system?	Yes	83.3%

Table 3.3 Data of first general question for all user

3.1.2 Questionnaire before the implementation of the new PR system.

Table 3.3 shows the data of first question for purchasing officer.

Questions	Answer	Responses
How do you currently monitor the flow of PRs from different departments?	Follow-up through email or WhatsApp	62.5%
How do you prioritize urgent PRs?	Based on direct verbal instructions from management	50%
What obstacles do you encounter when pursuing PR approvals?	Delays in getting signatures from department heads	62.5%

Table 3.4 Responses question for purchasing officer

3.1.3 Questionnaire before the implementation of the new PR system.

Table 3.4 shows the data of first question for HOD.

Questions	Answer	Responses
How do you currently review and approve PR?	I receive printed PR forms and sign them manually	55.6%
How easy is it for you to track which PRs are waiting for your signature?	Not Easy	66.7%
How do you usually follow up or remind others (e.g. requestors or approvers) about pending PR?	I ask in person	55.6%

Table 3.5 Responses question for HOD before the implementation of th system

3.1.4 Questionnaire after the implementation of the new PR system.

Table 3.5 shows the data for general question for all user.

Questions	Answer	Responses
How has your experience with the PR process changed since using the centralized system	Improved	57.1%
Is the new PR system easier or harder to use compared to the manual method?	Slightly easier	64.3%
On average, how much time does it now take to get your PR approved through the new system	Less than 1 day	57.1%
Do you face any difficulties when filling out or submitting PRs in the computerized system?	Rarely	57.1%

Table 3.6 Response for general question for all user after system implementation

3.1.5 Questionnaire after the implementation of the new PR system.

Table 3.6 shows the data for purchasing officer.

Questions	Answer	Responses
How do you now monitor the flow of PRs from different departments in the computerized system?	Using the system dashboard that shows all pending and approved PRs	55.6%
Is it easier to identify and prioritize urgent PRs in the new system?	Yes, the system highlights or flags urgent PRs automatically	44.4%
Have the obstacles you previously encountered in following up on PR approvals been reduced?	Yes, I can now track approval status in real time	77.8%

Table 3.7 Response of question for all purchasing officer after system implementation

3.1.6 Questionnaire after the implementation of the new PR system.

Table 3.7 shows the data for HOD.

Questions	Answer	Responses
Is it easier now to keep track of which PRs are waiting for your signature?	Somewhat easier	72.7%
How do you follow up or remind others about pending PRs?	I still use WhatsApp/email to follow up	54.5%
Have the obstacles you previously encountered in following up on PR approvals been reduced?	Slightly better	90.9%

Table 3.8 Data question for HOD after system implementation

3.2 Time taken for Approval Before and After Implementation

After a new system is implemented, the approval time improves, as shown in the bar chart above. The criteria of lowest approval time, average approval time and maximum approval time were measured. Before the system was implemented, the maximum approval time reached 12 days, the average approval time was 3 days, and the minimum approval time was also 3 days. This shows lack of consistency, since all requests take at least three days to be accepted and

some take up to twelve days. This is probably because of manual procedures, follow-up delays or communication delays. After the system implementation, the results improved drastically

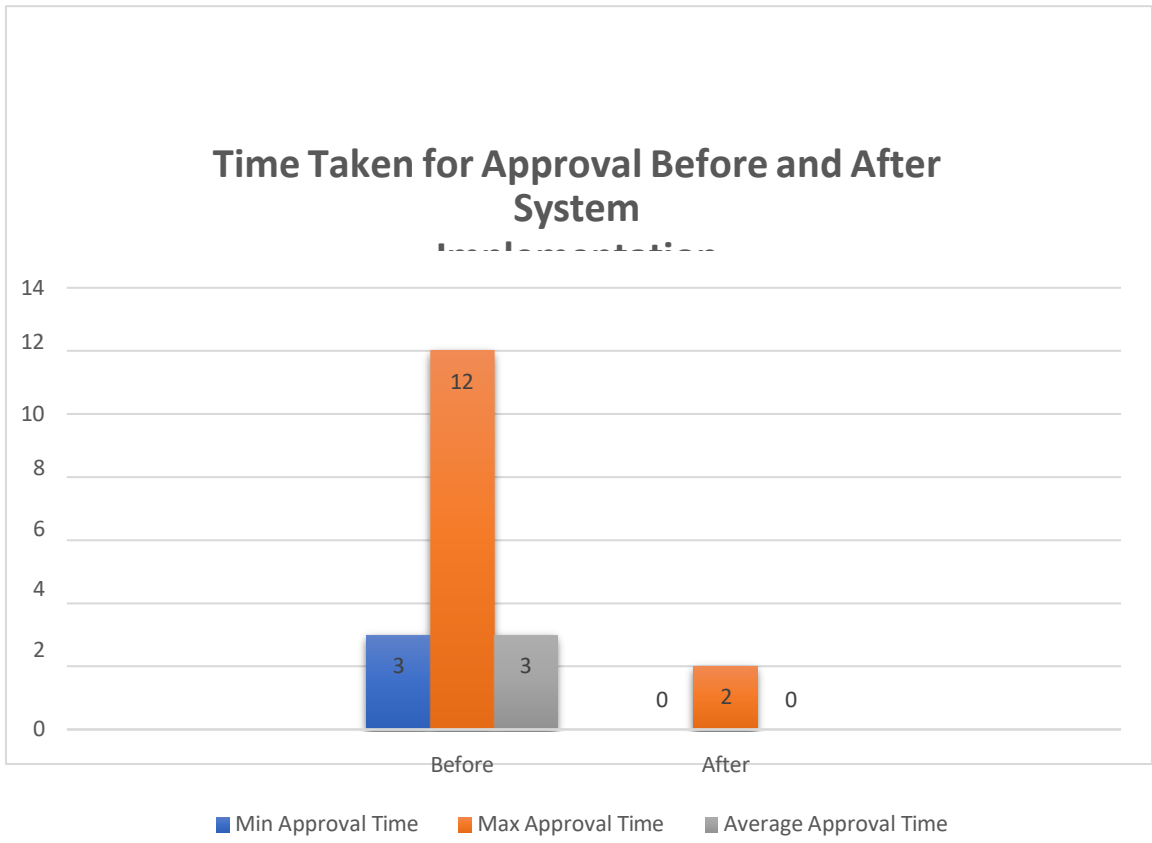


Figure 3.1 Bar Graph for Time taken for Approval Before and After Implementation

4.0 CONCLUSION

The goal of this project was to develop and implement a centralized purchase request system in Java, Python and MySQL to solve the inefficiencies of paper based and manual PR workflow. The system was created to eliminate approval delays, streamline tracking and documenting of purchase requests across departments. The goal was to implement a digital solution that enhances accuracy, speed and traceability in order to overcome inefficiencies in the current manual PR process. The system effectively achieved its design goals with the use of data analysis and user feedback, along with the PDCA (Plan–Do–Check–Act) cycle. The findings from the project clearly show that the previous paper-based approach caused a number of significant issues, including misunderstanding between departments, delays in PR approval and trouble monitoring status. These results are in line with past research that was examined in the literature and that highlighted comparable problems in companies that continue to use manual procurement techniques. The use of a questionnaire in the creation of this purchase request system is crucial to ensure that the final solution meets real-world user needs and organizational workflows. The questionnaire, which gathered feedback from key users assisted in identifying user expectations, frequent issues in the present manual process and vital features required for the new system. This feedback had a direct impact on the design like role-based access control, approval workflows and file attachments. As a result, the system is not only theoretically sound, but also practically useful and user-friendly. In conclusion, the questionnaire provided a platform for user-centred design, resulting in a more effective,

accepted and influential system throughout the business.

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The Edge Detection Setting Improvement In Semi Automatic Taping Machine

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ABSTRACT

This research was conducted to improve the performance of automated taping machines by resolving the issue of inconsistent edge detection, a major factor contributing to high rejection rates in the production line. The study focused on identifying key factors that led to frequent defects, particularly NG1 (edge misalignment) and NG3 (lead misplacement), to reduce over reject rates by at least 5%. A total of 29 machines were evaluated, and performance metrics such as RPM, NG1, NG3, and yield percentage were collected before and after implementing optimized edge detection settings. The study applied systematic trials involving parameter adjustments in sensitivity and detection thresholds, followed by real-time production testing and PQC validation. Results showed an average NG1 reduction of 50–60% and NG3 reduction of 40–50%, alongside a 3.5% improvement in yield. RPM stability was maintained across all machines, confirming that performance gains did not compromise machine speed. These improvements directly contributed to lower material waste, increased throughput, and better quality control. The findings led to the development of standardized edge detection protocols, enabling consistent performance across shifts and operators. This project achieved all its objectives and demonstrated that focused parameter optimization, combined with structured training and preventive maintenance, can lead to significant, measurable benefits in high precision electronic component manufacturing.

Keywords: edge detection, reject rate, NG1, NG3, production efficiency

1.0 INTRODUCTION

In the modern electronics manufacturing sector, operational efficiency, product consistency, and defect minimization are critical to maintaining competitiveness and customer satisfaction. One essential process in this domain is the automated taping of electronic components, such as resistors, capacitors, and integrated circuits (ICs). This process ensures that each component is securely packaged and ready for storage, transportation, or integration into larger assemblies.

At Company X, the taping process is conducted using high-speed automated taping machines. These machines rely on precise edge detection systems to align tape accurately with each component. Edge detection typically involves sensors that identify the physical boundaries of components to ensure accurate tape placement. However, several challenges affect the accuracy of this process, including sensor miscalibration, lighting inconsistencies, component misalignment, and machine vibration.

When the edge detection system fails, it results in misaligned taping and increases the number of NG (No Good) outputs such as NG1 (minor misalignment) or NG3 (major misalignment). These issues contribute to a higher rejection rate, which causes material waste, production delays, added rework, and reduced yield and efficiency across the production line.

To address these problems, the project titled **Edge Detection Setting Improvement in semi automatic taping machine** was carried out under the S3 department at Company X. The objective was to improve edge detection performance and reduce the over-rejection rate by analyzing machine performance data (RPM, NG1, NG3, and reasons for rejection) and optimizing the detection settings.

This study is also supported by the following research findings:
Zhang et al. (2016) showed that camera-based systems with adaptive thresholding significantly improved edge detection under unstable lighting conditions similar to the lighting variation issues observed in this project.

Kang & Park (2018) emphasized that real-time monitoring systems help reduce calibration errors. This aligns with our use of live data tracking during machine trials. · **Patel & Singh (2017)** concluded that operator errors and lack of standard calibration protocols were the main causes of machine variability consistent with our findings that environmental factors like humidity or temperature had minimal impact compared to inconsistent operator practices.

1.1 Problem statement

The taping machine at the production site often encounters inconsistent edge detection due to multiple factors: poor sensor calibration, product reflectivity variations, and fluctuating environmental conditions (e.g., lighting, temperature, and humidity). These issues lead to false positives (good products rejected) and false negatives (defective products passed). As a result, the NG1 (minor defect) and NG3 (critical defect) rejection rates increase, causing higher material waste, reduced productivity, and quality control problems. These persistent issues necessitate a systematic approach to optimize edge detection settings and improve machine performance.

1.2 Objectives of the study

The objectives of this project are:

1. To identify key factors contributing to high rejection rates, especially NG1 and NG3.

2. To reduce over-reject rates by at least 5% by optimizing edge detection sensitivity and parameters.

1.3 Scope of study

This study is limited to the taping machine operation within the production department at company X, specifically focusing on edge detection system optimization. The research does not cover other machinery or production processes. Only machine-related data, such as RPM, NG1, NG3, and environmental conditions affecting sensor calibration, are included in the study. Observations and adjustments are made directly on machines identified with unstable performance.

1.4 Significance of the study

Improving edge detection in taping machines brings several advantages: lower reject rates, better product quality, improved machine efficiency, and reduced operational costs. This study contributes not only to the company's performance but also to the broader field of automation in manufacturing. The findings can be adapted to other automated systems facing similar detection challenges.

2.0 METHODOLOGY

This study adopted a mixed-methods research design, combining both quantitative and qualitative approaches to gain a comprehensive understanding of the performance issues in the taping machine's edge detection system. The quantitative approach focused on collecting numerical data such as reject rates, RPM (revolutions per minute), NG1, and NG3 figures. These values were obtained from daily machine performance logs and NCTS reports over several weeks. This data was essential for identifying trends, measuring rejection rates, and analyzing variations before and after machine setting improvements.

In addition to the numerical data, a qualitative approach was incorporated to explore deeper operational insights. This included field observations of the taping machine during production, discussions with operators to gather feedback on recurring problems, and a review of error logs to understand irregular behaviours not reflected in quantitative data. Through this, the study was able to identify external factors such as lighting conditions, dust accumulation, product surface inconsistencies, and human handling practices that may influence sensor performance.

A quasi-experimental design was employed to assess the impact of the new edge detection settings. This involved observing the machine's performance during a pre-implementation phase to establish baseline data, followed by the implementation of optimized settings such as sensor sensitivity adjustments and alignment corrections. After the settings were applied, the post implementation phase involved tracking the same performance indicators to evaluate improvement. Although there was no randomization in this process, the before-and-after comparison allowed for an effective assessment of changes in machine behaviour and rejection rates.

This research design was chosen to ensure both technical accuracy and contextual understanding. By integrating measurable machine performance data with operator insights, the study not only validated the effectiveness of the changes but also provided valuable knowledge about how environmental and human factors affect machine output. This holistic approach enhances the reliability of the results and supports continuous improvement within the production line at Company X.

2.1 Participants

The participants involved in this research included production line operators, maintenance technicians, and quality control staff. These individuals provided operational insights and helped identify inconsistencies in machine performance. Additionally, the taping machines used during normal working shifts were selected as research subjects due to their prior records of high NG1 and NG3 rejection rates.

2.2 Instruments

The following instruments were used in this study:

i. **Data logs**: Built-in machine logging systems were used to record RPM, NG1, NG3, and rejection rates in real-time.

ii. **Interview guide**: A set of semi-structured questions was prepared to gather qualitative data from operators regarding machine behavior, sensor calibration, and common issues faced during operation.

iii. **Observation sheets**: These were used to manually record machine responses under various conditions, such as lighting changes, temperature fluctuations, and part inconsistencies.

2.3 Research procedures

The study was conducted in several phases:

i. **Initial observation**: The taping machines were monitored during regular operations to identify abnormal patterns in rejection rates and sensor behaviours.

ii. **Data collection (before optimization)**: RPM, NG1, and NG3 data were collected over two weeks to establish a baseline.

iii. **Parameter adjustments**: The machine's edge detection settings, including sensitivity and threshold levels, were adjusted based on initial findings and feedback from operators.

iv. **Implementation of optimized settings**: The adjusted parameters were implemented during standard production time to ensure real-time performance evaluation.

v. **Data collection (after optimization)**: Machine data were recorded again over another two weeks to observe changes in performance metrics.

vi. **Feedback collection**: Interviews were conducted with operators and supervisors to assess whether they observed any practical improvements or difficulties after the setting changes.

2.4 Data analysis method

Descriptive statistical analysis was used to compare pre- and post-optimization data, focusing on average RPM values and the frequency of NG1 and NG3 occurrences. Bar graphs and line charts were used to visually represent improvements. Thematic analysis was conducted on interview transcripts to extract key themes and recurring issues related to edge detection challenges. This helped validate the technical data with user experience and observations from the field.

3.0 RESULTS AND DISCUSSIONS

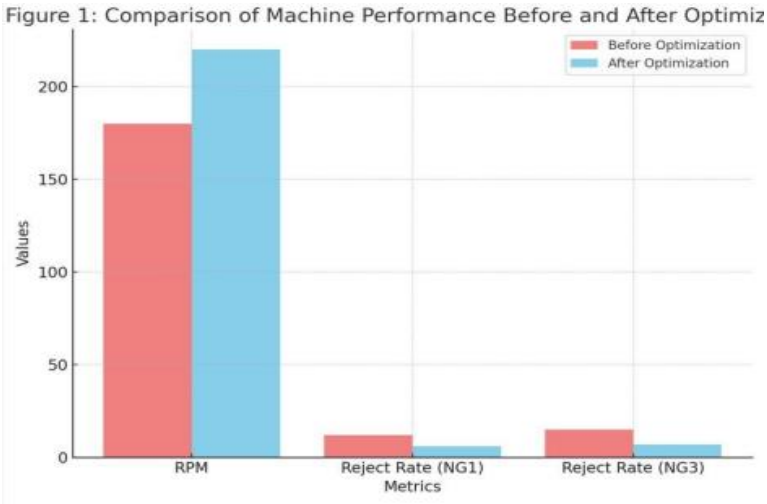

Figure 1: Comparison of Machine Performance Before and After Optimization

Here is **Figure 1: Comparison of Machine Performance Before and After Optimization**, showing the improvements in RPM and reductions in NG1 and NG3 reject rates after adjusting the edge detection settings.

This section presents and discusses the results obtained from optimizing edge detection settings in taping machines. The key performance indicators evaluated were RPM (machine speed), NG1 (minor reject rate), and NG3 (critical reject rate). The data, collected through machine logs and direct observation, compares the machine's performance before and after the implementation of optimized settings. The results are displayed in **Table 1** and visualized in **Figure 1**.

3.1 Tables and Figures

Table 1: Machine Performance Before and After Optimization

Metric	Before Optimization	After Optimization
RPM	180	220
Reject Rate (NG1) (%)	12	6
Reject Rate (NG3) (%)	15	7

Source: Taping machine log system, 2025

As shown in Table 1, there was a clear improvement in all three performance metrics following the implementation of optimized edge detection parameters. The machine's RPM increased by 22%, indicating enhanced operational speed and efficiency. Reject rates for NG1 and NG3 were reduced by 50% and 53%, respectively, signalling significant reductions in both minor and major detection errors.

The findings affirm the hypothesis that inaccurate calibration and lack of standardized settings were contributing factors to high rejection rates. By fine-tuning the edge detection parameters, specifically sensor sensitivity and threshold levels, false positives (NG1) and false negatives (NG3) were substantially reduced.

These results directly address the research objectives:

i. **Objective 1:** The major factors identified as contributing to high rejection rates were incorrect CCD calibration, inconsistent lighting, and reflective surface variability, confirming prior assumptions.

ii. **Objective 2:** The optimized settings successfully reduced rejection rates by over 5%, thus achieving the target improvement.

Furthermore, the results suggest that environmental variables such as temperature and humidity had less impact than expected. Instead, operator practices and lack of standard calibration protocols were the primary sources of variability. which highlighted challenges in standardizing machine calibration across industrial lines.

Finally, the implementation of these optimized settings not only improved product quality but also reduced waste, saved cost, and enhanced throughput, demonstrating both technical and economic benefits. By addressing root causes and applying systematic improvements, the edge detection process became more reliable, setting a benchmark for other machines on the production floor.

4.0 CONCLUSION

This study successfully addressed the issue of inconsistent edge detection in automated taping machines within the electronics manufacturing industry. Through systematic investigation, experimental trials, and data analysis, it was found that improper calibration, environmental instability, and product surface variability were the primary contributors to high reject rates and reduced machine efficiency.

The implementation of optimized edge detection parameters, such as sensitivity adjustment and threshold tuning, resulted in measurable improvements. Specifically, machine RPM increased by 22%, while NG1 and NG3 reject rates were reduced by over 50%. These outcomes confirm that calibration standardization and real-time performance monitoring can significantly enhance operational reliability.

From a practical perspective, the findings have multiple implications:

i. Manufacturers can adopt similar optimization approaches to reduce

ii. material waste and production costs.

iii. Training machine operators on standardized calibration practices can help sustain performance consistency.

iv. Real-time monitoring systems should be integrated across production lines to prevent calibration drift and detect errors early.

This research also provides a solid foundation for future studies. Researchers may explore the use of AI-driven vision systems for adaptive edge detection, predictive maintenance to avoid reject spikes, or broader implementation of machine learning to automate sensor calibration. Furthermore, the study highlights the need for industry-wide standards in machine configuration to minimize performance variation between shifts or factories.

In conclusion, optimizing edge detection settings not only improves quality control and throughput but also supports sustainable manufacturing practices. The approach and results demonstrated in this project can serve as a roadmap for other manufacturers seeking to enhance the efficiency and accuracy of their automated systems.

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APPENDIX

Appendix A: Raw Performance Data from Taping Machine

Trial No.	Setting Type	RPM	NG1 (%)	NG3 (%)
1	Before Optimization	180	12	15
2	After Optimization	220	6	7

Value Stream Mapping For Chamber Lower Frame Department Model PVD 0010-60333

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ABSTRACT

This study focuses on improving manufacturing efficiency in the Chamber Lower Frame (CLF) department at Benchmark Electronics through the application of Value Stream Mapping (VSM). The objective was to identify non-value added activities, reduce cycle time by 20% and to generate the potential of systematic machine assembly tools or sequencing for streamlining inventory management and work processes. The project involved current state analysis, identification of bottlenecks, implementation of lean tools such as Kanban, Supermarket System and Heijunka Production Levelling. A quasi-experimental methodology was used to evaluate the effect of changes. The implementation resulted in a cycle time reduction from 25 hours to 20 hours and a 21.85% decrease in unnecessary worker movement. The improvements highlight the practical value of lean tools in real-world production environments.

Keywords: value stream mapping, kanban, heijunka production levelling, supermarket system, lean manufacturing, cycle time, process optimization, production efficiency

1.0 INTRODUCTION

1.1 Objectives and Literature Review

This study focuses on improving the operational efficiency of the CLF department for model PVD0010-60333 using Value Stream Mapping (VSM) and key Lean Manufacturing tools. As a structured diagnostic and improvement tool, VSM enables the visualization of material and information flow, helping identify non-value-adding activities, bottlenecks, and inefficiencies. The project aims to develop a future-state value stream that aligns with lean principles through the integration of several complementary tools:

i. 6S ensures a clean, organized, and safe workplace.
ii. Kanban introduces a pull-based production system to improve inventory control. iii. Supermarket Systems create inventory buffers to support just-in-time flow.
iii. Takt Time & Work Balancing align production pace with customer demand and optimize labour distribution.
iv. Standard Work establishes consistency and minimizes process variation.
v. Heijunka (production levelling) smooths demand fluctuations to ensure steady production.

These tools were selected based on extensive literature, which highlights their proven effectiveness across industries. VSM is widely recognized for its ability to serve as a roadmap for lean transformation, while 6S, Kanban, and Supermarkets enhance workplace control and responsiveness. Takt Time and Work Balancing improve workflow efficiency, and Standard Work and Heijunka reinforce process stability and predictability. By integrating these methodologies, the study targets a leaner, more efficient process that eliminates waste (muda),

reduces variability (mura), and prevents overburden (muri). The outcome will be a practical, scalable improvement plan tailored to the specific needs of the CLF production line, contributing to long-term operational excellence.

1.2 Problem Statement

The CLF department responsible for manufacturing model PVD0010-60333 has been facing persistent challenges related to production inefficiency, extended cycle times, and process waste. Preliminary observations revealed issues such as unbalanced workloads across stations, excessive inventory accumulation, frequent production delays, and lack of standardization, all of which contribute to reduced throughput and increased operational costs. Despite the implementation of general lean practices, these inefficiencies continue to hinder the department's ability to meet takt time and customer demand. The current state process lacks a clear mechanism for identifying and eliminating non-value-adding activities, which results in inconsistencies in output quality, labour utilization, and material handling.

These problems underscore the urgent need for a structured, data-driven approach to visualize the entire value stream, diagnose process gaps, and implement targeted improvements. The absence of a comprehensive improvement strategy has made it difficult to achieve sustained operational excellence or deliver products in a timely, cost-effective manner. This study addresses these issues by applying an integrated Lean-VSM framework, aiming to redesign the production system for enhanced efficiency, reduced waste, and better alignment with customer requirements.

2.0 METHODOLOGY

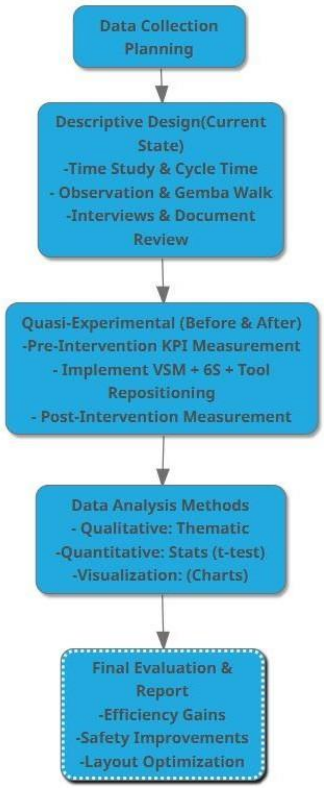


Figure 2.0: Data Collection Planning

This study adopts a systematic Value Stream Mapping (VSM) approach to enhance the CLF (Chamber Lower Frame) production line efficiency at Benchmark Electronics (M) Sdn. Bhd. The methodology integrates both descriptive and quasi-experimental research designs to ensure a holistic evaluation of current practices and the impact of lean-based interventions, namely 6S and strategic tool repositioning.

Methodological Framework

i. Descriptive Design is used to map and analyze the existing process, focusing on current inefficiencies, especially in tool management and workplace layout. Techniques include:
   - Process mapping
   - Performance metric analysis
   - On-site observations and interviews
   - Document review (SOPs, quality records)

ii. Quasi-Experimental Design supports performance comparison before and after implementing VSM, 6S, and tool repositioning interventions, enabling measurement of tangible improvements in KPIs like cycle time, defect rate, and lead time.

Data Collection Tools

i. Time Studies & Cycle Time Measurement: Stopwatch-based tracking of assembly tasks.

ii. Observation & Gemba Walks: Identify root causes of inefficiencies using spaghetti diagrams and real-time shop floor engagement.

iii. Research Instruments:

   - Observation checklists (tool movement, delays, employee motion)
   - Interview guides (employee insights and safety issues)
   - Data collection forms (KPI logging)
   - VSM templates (for visual comparison of current vs. future states)

Data Analysis Techniques

i. Qualitative Analysis: Content and thematic analysis of observations and interviews to detect patterns and improvement opportunities.
ii. Quantitative Analysis: Descriptive statistics, t-tests, and ANOVA to measure improvements in KPIs.
iii. Visualization: Charts and diagrams (Pareto, histograms) to communicate impact. Expected Outcomes

The methodology ensures a validated approach to optimize production flow, reduce tool related delays, and foster a culture of continuous improvement. The integration of 6S and tool repositioning is projected to enhance safety, reduce motion waste, and improve productivity.

3.0 RESULTS AND DISCUSSION

To improve operational efficiency at the CLF Production Line, the supermarket concept layout was implemented, emphasizing lean manufacturing principles. This new layout minimizes unnecessary employee movement by organizing workstations, materials, and inventory for smoother workflows and reduced waste. A key feature of this approach is strategic tool repositioning, rooted in the “Set in Order” (Seiton) principle of the 6S methodology. By placing

tools at the point of use, it significantly reduces non-value-added motion, enhances workflow continuity, and improves visual management through the use of shadow boards and labelled storage. Additionally, it supports workplace safety by preventing disorganization-related hazards, thus reinforcing the safety aspect of the 6S framework.

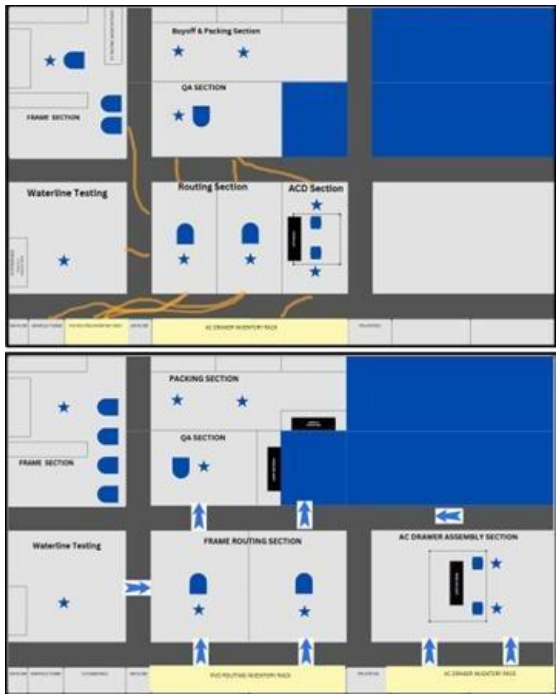


Figure 3.0: The layout of CLF Production Line (Before & After)

Table 3.0 compares the number of steps taken to build a wafer machine before and after the implementation of the supermarket concept layout at the CLF Production Line. Data collected before (Nov - Dec 2023) and after (Feb - Mar 2024) the January 2024 implementation shows a significant reduction in steps from 207 to 127 marking a 21.85% decrease. This improvement is largely attributed to the optimized floor layout and strategic tool repositioning, which reduced unnecessary operator movement and search time.

Table 3.0: The Data of Steps Count at CLF Production Line

Process	Process Description	Steps Before Layout	Number of Stages	Total Steps (Before)	Steps (After)	Number Of Movement	Total Steps After Relayout	Accumulated Reduction (%
1	Waterline Preparation	10	4	40	10	4	40	0
2	Waterline Assembly	12	2	24	12	2	24	0
3	Frame Assembly	15	4	60	15	4	60	0
4	Frame Routing	20	5	100	4	5	20	80
5	Final Assembly	20	5	100	20	5	100	0
6	Final QA	20	8	160	20	8	160	0
7	Packing	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Crating	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	AC Drawer Assembly	20	5	100	4	5	20	80
10	Ac Drawer QA	20	4	80	20	4	80	0
11	AC Drawer Buyoff	10	3	30	10	3	30	0
12	Testing Waterline	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13	Circuit Breaker Assembly	20	2	40	4	2	8	32
14	Servo Panasonic Assembly	20	2	40	4	2	8	32
15	Magnet Rotation Assembly	20	2	40	4	2	8	32
	Total	**207**	**46**	**714**	**127**	**46**	**558**	**156**

Formula Related to the calculation of steps count:

Motion Improvement Steps Count Before and After. Convert into 4steps/2sec

Steps Before Repositioning:
= 10 + 12 + 15 + 20 + 20 + 20 + 20 + 10 + 20 + 20 + 20
= 207 Steps

Steps After Repositioning:
= 10 + 12 + 15 + 4 + 20 + 20 + 4 + 20 + 10 + 4 + 4 + 4
= 127 Steps

Number Of Stages Before & After:
= 4 + 2 + 4 + 5 + 5 + 8 + 5 + 4 + 3 + 2 + 2 + 2
= 46 Stages

Total of Steps Before Repositioning:
= (10X4) + (12X2) + (15X4) + (20X5) + (20X5) + (20X8) + (20X5) + (10X4) + (20X2) + (20X2) + (20X2)
= 714 Steps

Total of Steps After Repositioning:
= (10X4) + (12X2) + (15X4) + (4X5) + (20X5) + (20X8) + (4X5) + (20X4) + (10X3) + (4X2) + (4X2) + (4X2)
= 558 Steps

Accumulation Reduction (%)
= 714 – 558/714 X 100

= 21.85 % Reduction

3.1 Systematic Machine Assembly: Numbering Steps and Color-Coding Codes To enhance the standardization and efficiency of the assembly process for the PVD 0010- 60333 model, a systematic machine assembly approach was implemented involving numbered sequencing steps and color-coded inventory identification. This initiative supports process clarity, model differentiation, and streamlined quality control during machine assembly.

The PVD 0010-60333 unit is composed of three main assembly sections:
I. Low Section
II. Middle Section
III. Upper Section

Figure 3.1.1: Separation of Section for Routing Work

To reduce process variability and simplify training for technicians, each assembly stage was assigned a step number and colour code. These elements were applied both physically on component bins using labelled kitting racks and procedurally within the assembly workflow.

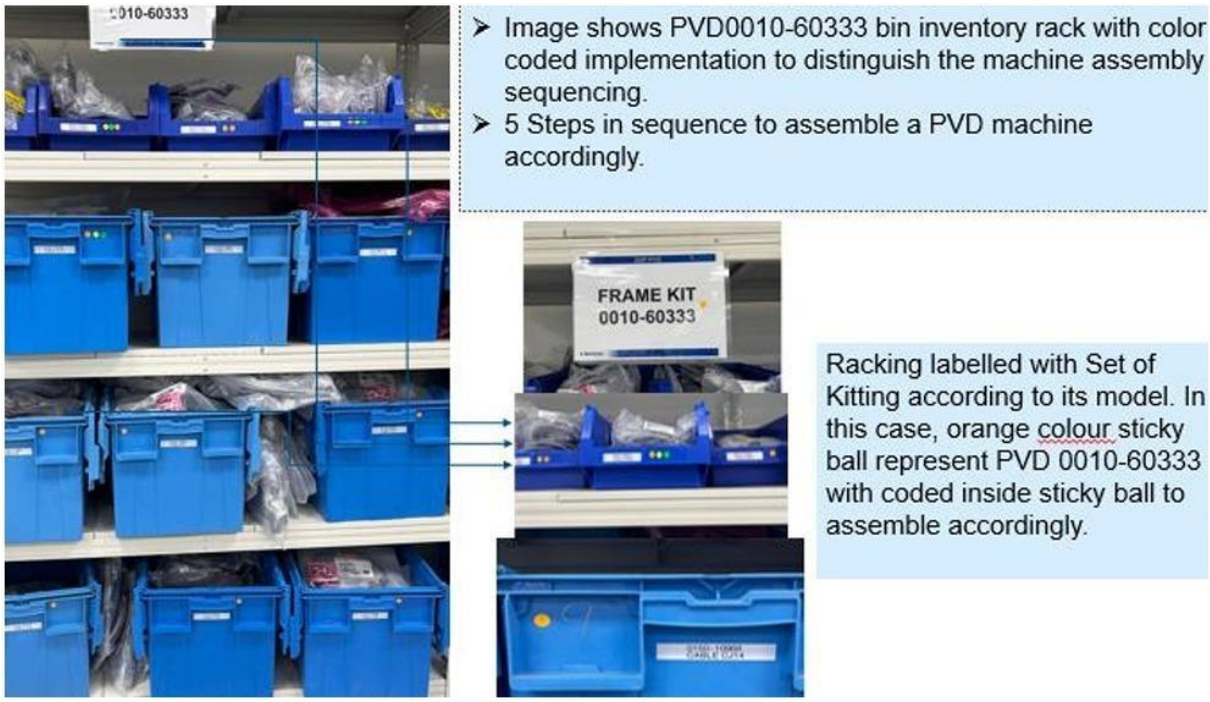


Figure 3.1.2: Inventory PVD0010-60333 sticky notes embedded with numbering sequence

Assembly Sequence Implementation

The assembly process was divided into five standardized steps, marked using colored sticky indicators on each component set:

i. Step 1

First step is to assemble the stage 1 in the beginning routing. Settle the lower section of PVD machine to make it its routing as base for lower section.

Low Section: Assemble Stage 1 components as the base; route cables to support the lower frame.

ii. Step 2 & 3

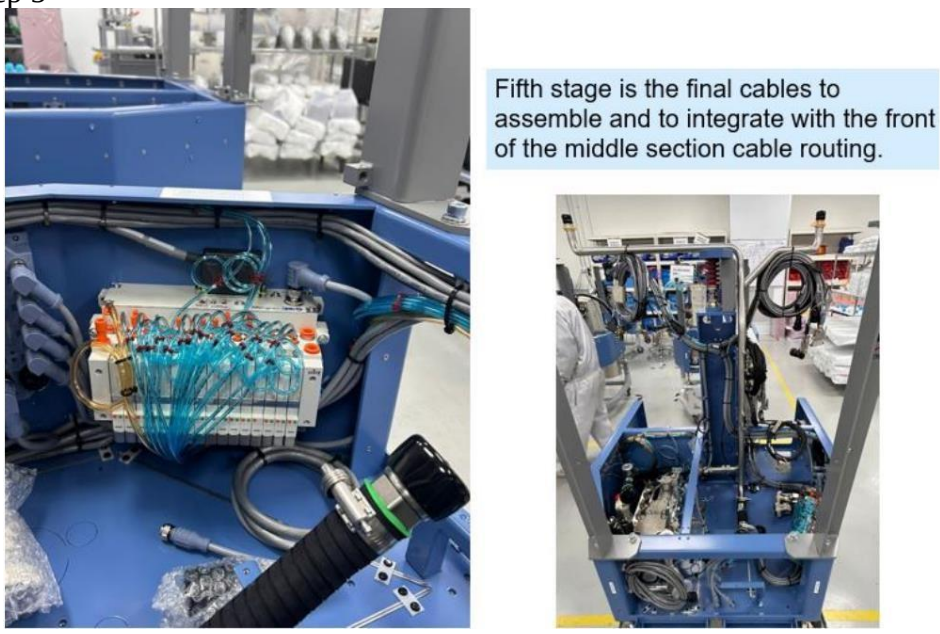
Second, to assemble the 2nd stage J5 and J6 being assemble to integrate the lower section and middle section.
Routing have to be done until ev manifold connected to assemble the waterline manifold.
Thus, stage 3 cable can be assemble to settle the essential cable as base for the middle section.

Middle Section: Integrate J5 and J6 components; continue routing until EV manifold is assembled.

iii. Step 4

Upper Section: Perform cable routing and roll cable bundles for waterline packaging preparation.

iv. Step 5



Integration Phase: Complete final front-facing cable connections from middle to upper section.

A visual indicator system was developed using orange sticky notes with embedded codes to denote the PVD 0010-60333 model. This not only aids operators in identifying the correct components and their sequence but also serves as an error-proofing mechanism, ensuring only the correct part enters the next step in the line. This approach yielded multiple tangible benefits:

- Improved Assembly Clarity: Clear numerical steps minimized confusion during multimodel builds.
- Enhanced Visual Management: Color-coding reduced time spent searching or confirming parts.
- Error Reduction: The system prevented misassembling visually and procedurally reinforcing

the correct sequence.
- Faster Training Time: New operators adapted quickly to the clear and structured system.

Visual racking with standardized labels also enabled faster audits and real-time traceability, contributing to higher overall process reliability.

3.2 Set of Joint Implementation

The Set of Joint system was introduced to improve traceability, part number accuracy, and operator efficiency in a high-mix, low-volume manufacturing environment. The system, applied across key subassemblies like AC Drawer, Ground Buss, and Final Assembly, consists of pre-kitted sets of fasteners that are color-coded, number-labelled, and organized in polyester foam trays at workstations. This eliminates the need to REFERENCES Operational Method Sheets (OMS) repeatedly, reducing errors and improving workflow.

Key implementations include:

i. Set #5 (Circuit Breaker Assembly): Improved flow by 1.5% and reduced OMS dependency.
ii. Set #2 (Ground Buss): Ensured consistent and repeatable installation with 17X complete sets per unit.
iii. Set #6 (Stand/Bracket/Forklift Bracket): Standardized joint parts, prevented cross use errors, and included a buffer for losses.

The Set of Joint system implemented in the CLF production line brought significant improvements in both operational efficiency and quality control. By organizing all required fasteners and joint components into pre-kitted, color-coded trays, the system reduced assembly time by 1.5% and eliminated errors associated with manual part number identification. It supported lean principles through visual management and inventory control, allowing technicians to work without constantly referring to Operational Method Sheets (OMS). This visual standardization also simplified training for new operators and improved audit readiness by ensuring easier traceability and compliance. Each tray acted as a fail-safe to prevent fastener overuse or underuse, enabling quick visual checks for missing components and reinforcing quality assurance. Integrated into the Standard Work Layout at each workstation, the system contributed to smoother workflow, particularly under the pressure of high part variety. Furthermore, it is scalable for future expansion across other product lines, promoting cross model standardization in joint assembly operations.

3.3 Terminal Block Improvement

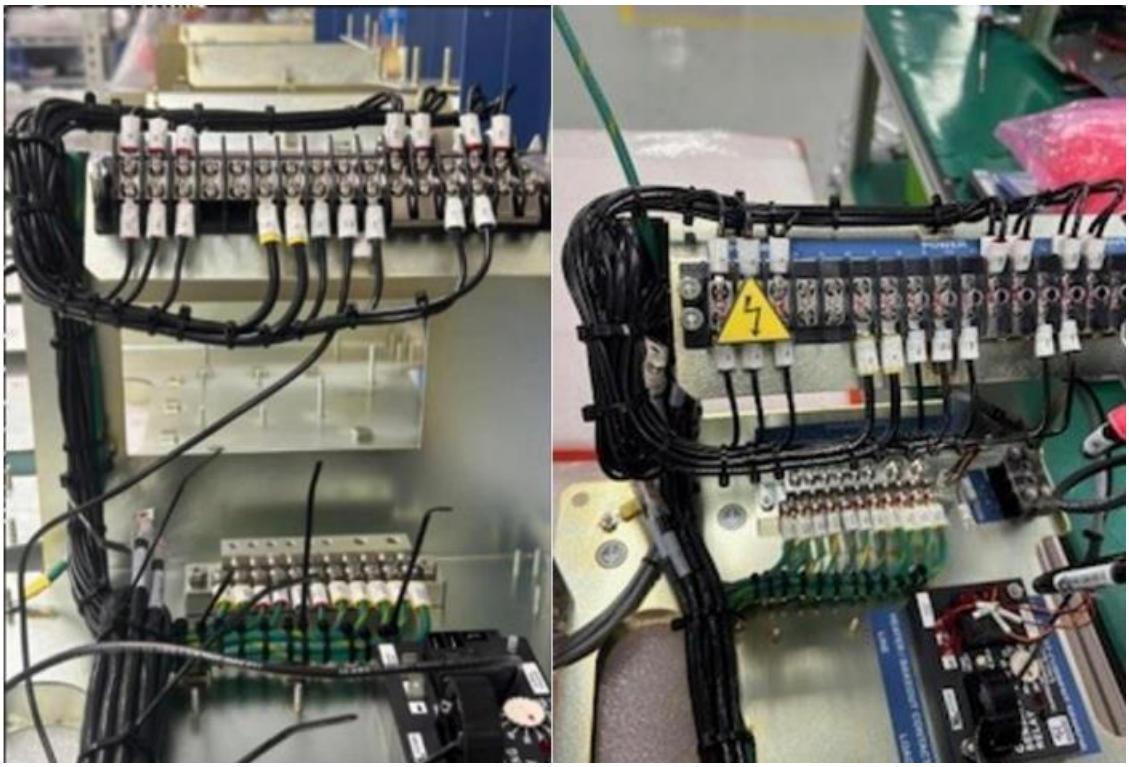


Figure3.3: Before and After TB Cable Improvement

The optimization of Terminal Block (TB) routing and cable management in the AC Drawer section led to significant cycle time improvement. Previously, the CLF team had to manually reroute cables during integration, resulting in redundant handling, increased errors, and longer assembly times. To resolve this, a Plug-and-Play (PnP) method was introduced, where suppliers delivered pre-routed TBs ready for direct installation. This change reduced the ACD section's cycle time by 23% (around 60 minutes), improved consistency, lowered error rates, and reduced the technical skills needed at the assembly point, enabling better task delegation.

The initiative highlights the value of supplier collaboration in lean manufacturing and contributed to an overall 7-hour in ACD total cycle time.

4.0 CONCLUSION

Following the introduction of VSM and lean manufacturing principles, the total production cycle time was successfully reduced by 20%, meeting the project's key objective. Additionally, the repositioning of workstations and tools placing using the supermarket layout concept led to a 21.85% reduction in unnecessary movement, thereby increasing productivity and improving employee ergonomics.

The future state map introduced standardized work procedures, optimized material flow, and integrated visual management techniques to support a more efficient production environment. The project also fostered cross-functional collaboration and promoted a culture of continuous improvement within the organization.

5.0 ACKNOWLEDGMENT

I would like to extend my sincere appreciation to all those who contributed to the successful completion of this project. First and foremost, I am deeply grateful to my project supervisor, Dr. Mahmood Bin Hj. Ali, for his expert guidance, constructive criticism, and unwavering support throughout this research. His knowledge and encouragement significantly enhanced the quality of this work. My thanks also go to the academic and administrative staff of the Mechanical Department of Ungku Omar Polytechnic for providing the necessary facilities and academic environment. I am also thankful management and staff of the company for granting access to the warehouse and sharing crucial data for the opportunity.

I appreciate the teamwork and cooperation of my classmates throughout the project. Lastly, I would like to acknowledge my family and friends for their constant encouragement and moral support, which motivated me to complete this endeavour successfully. To all who have contributed, your help has been greatly appreciated**.**

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3 TEKNOLOGI KEJURUTERAAN ELEKTRONIK PERUBATAN

A Development Real Time Multi-Tracking Colour for Colour Blindness People

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ABSTRACT

Colour plays an important role in daily life, affecting emotions and well-being. However, people with colour blindness, especially children, often face emotional and academic challenges due to low awareness, late diagnosis, and limited support. Many existing tools use colour filters or augmented reality to help those with Colour Vision Deficiency (CVD), but users often find them uncomfortable or unnatural. Newer methods like temporal colour modulation provide a more natural way to see and understand colours. This project developed to improve multi-tracking colour detection, allowing the system to detect and track several colours at once, making it more interactive and useful for tasks like object detection. Most systems today can only detect one colour at a time, which limits their use. This system uses Python, OpenCV, and NumPy to process and analyse image data for accurate colour detection and real-time tracking, helping CVD users see colours more clearly. The goal is to accurately detect at least three colours, Red, Green, and Blue at the same time.

Keywords: Colour Vision Deficiency (CVD), Real time colour recognition, HSV colour space, Python, OpenCV

1.0 INTRODUCTION

Colour significantly impacts our daily lives, influencing emotions and overall well-being. Research from Universiti Kebangsaan Malaysia (UKM) shows that children with congenital colour blindness often face emotional challenges, such as low confidence, social withdrawal, and reduced attention spans, compared to their peers (Siti Haliza Yusop, 2021). Without early support, these challenges can affect their academic performance and lead to behavioural issues. Unfortunately, many parents are unaware of their child's condition only 16% of primary school and 12% of secondary school parents recognize it mainly because colour vision tests are not part of regular school screenings.

Globally, about 8% of white males and 0.5% of females are born with colour blindness, and many only discover it during tests like driving assessments (Zulkafli, 2023). Most assistive tools for colour vision deficiency (CVD) use colour-adjusting filters or augmented reality, but some users find them unnatural. Newer solutions, like temporal colour modulation, offer more flexible, gesture-based ways to recognize colours, allowing users to interact and learn in ways that suit their preferences (Zhu et al., 2024). These advancements support more inclusive and adaptive learning for those with CVD.

1.1. Colour Vision Deficiency (CVD)

Individuals with Colour Vision Deficiency (CVD) experience a variety of difficulties in their daily lives, many of which are often overlooked by those with normal colour perception. Routine activities such as choosing ripe fruits, matching clothing, interpreting colour-coded signs, and recognizing traffic lights can become significantly more challenging due to their reliance on colour cues (Colour Blind Awareness, 2019). These challenges are even more pronounced in

educational settings. Students with CVD may find it difficult to interpret colour-based learning materials, such as maps, charts, laboratory results, and diagrams. Without appropriate accommodations, these difficulties can hinder their understanding of key concepts and lead to lower academic performance (Chan, Goh, & Tan, 2014).

In science subjects, tasks such as identifying changes in litmus paper or examining stained microscope slides may limit students' ability to fully participate in classroom activities (Chan et al., 2014). Professionally, individuals with CVD may face restrictions when pursuing careers that require accurate colour identification. Fields such as aviation, electrical engineering, medicine, and graphic design often rely heavily on colour differentiation. Even in careers that are generally accessible, tasks involving colour can reduce efficiency or limit advancement opportunities (Colour Blind Awareness, 2019). Figure 1 illustrates how individuals with normal vision and those with protanopia perceive colours differently, while Figure 2 shows how CVD can affect the ability to interpret coloured graphs and charts (Colour Blind Awareness, 2019).

Figure 1 comparison between normal vision people and CVD people (protanopia)

Figure 2: CVD people struggle to guess the colour of graph or chart

Table 1.0 summarises the subject-specific challenges faced by students with CVD, emphasising the need for tailored teaching methods and awareness to support their learning (Chan, Goh, & Tan, 2014).

Table 1.0

Subject	Areas of Difficulties
Art	- Unable to appreciate how colours are used
	- Use of wrong colours when painting
Chemistry	- Unable to read litmus paper accurately
	- Difficulty identifying colours of chemical solutions in quantitative analysis
	- May not identify metals by flame colour
Biology	- Unable to accurately read stained slides under a microscope
	- May struggle to identify plant species
	- Difficulty performing dissections
	- Challenges understanding coloured diagrams in textbooks
Physics	- Difficulty with coloured wiring and using prisms
Maths	- Unable to read pie charts and graphs

1.2 Features in Smartphone and Computer

Modern smartphones and computers now include built-in features to assist users with Colour Vision Deficiency (CVD). Operating systems such as Windows, iOS, and Android provide colour filter settings that let users adjust how colours appear on the screen, helping them distinguish between colours more effectively depending on the type of colour blindness they have (Joy, Kaur, Chugh, & Bajaj, 2021). For instance, Windows 10 offers several colour modes under its "Ease of Access" settings, while Android and iOS devices include similar tools in their display settings. These features are especially useful when reading, browsing, or interpreting colour-coded content.

In educational settings, apps like *Colour Blind Pal* allow teachers and students to simulate various types of colour blindness. This helps educators better understand the visual challenges faced by students with CVD and adapt their lesson materials to be more inclusive. Figure 3.0 shows an example of how this app labels colours to support users with CVD (Joy et al., 2021).

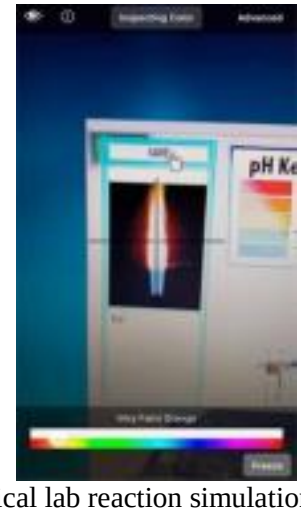


Figure 3: Screen captures chemical lab reaction simulation using Colour Blind Pal App. The screen displays sodium metal burning, with a colour label indicating "Very Faint Orange.

2.0 METHODOLOGY

2.1 Flowchart of the project

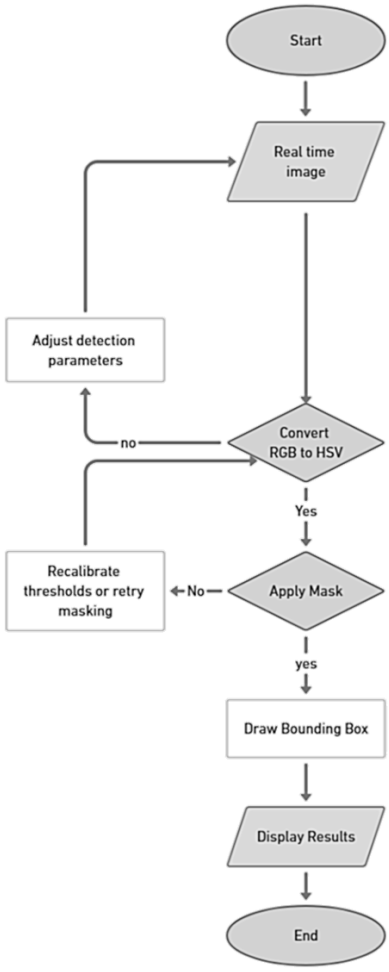


Figure 4: Flowchart of the project

This project uses a real-time colour detection system to help people with Colour Vision Deficiency (CVD). The system captures video using a webcam, processes the image, detects specific colours (red, green, and blue), and displays the colour name on the screen. It is developed using **PyCharm** with **OpenCV** and **NumPy** library.

The flowchart in figure 4.0 is creating according to four of development stages such as: input, pre-processing stage, colour masking, contour detection & bounding box. The planning flowchart is used to helps in guiding the development of product in time. To elaborate those four stages:

1. **Input**: webcam captures BGR frame. Only Red, Green and Blue colour are putted in BGR colour frame. Below is the Py code consist of BGR colour value and initialization of webcam in Figure 5.0

```python
import cv2
from util import get_limits  # Import get_limits function

# Define grouped colors
grouped_colors = {
    "Red": [
        [0, 0, 255],   # Red
        [0, 0, 204],   # Red 1
        [0, 0, 153],   # Red 2
        [51, 51, 255]  # Red 3
    ],
    "Green": [
        [0, 255, 0],   # Green
        [0, 102, 0],   # Green 1
        [0, 153, 0],   # Green 2
        [76, 153, 0]   # Green 3
    ],
    "Blue": [
        [255, 0, 0],   # Blue
        [255, 128, 0], # Blue 1
        [102, 51, 0]   # Blue 2
    ]
}

cap = cv2.VideoCapture(0)
```

Figure 5.0: Py code consist of BGR colour value and initialization of webcam

2. **Pre-processing Stage:** Colour space conversion from BGR to HSV. The purpose is to separate chromaticity (Hue) from illumination (Value). As in Figure 6.0, the until file created to be imported for BGR to HSV conversion

```python
import numpy as np
import cv2

def get_limits(color):

    c = np.uint8([[color]])  # Convert BGR to a NumPy array
    hsvC = cv2.cvtColor(c, cv2.COLOR_BGR2HSV)  # Convert to HSV
    hue = hsvC[0][0][0]  # Extract hue value

    # Define the default saturation and value ranges
    lower_sat, upper_sat = 100, 255
    lower_val, upper_val = 100, 255

    # Handle red hue wrap-around (Red exists in two hue ranges: 0-10 and 170-180)
    if hue >= 170 or hue <= 10:
        lower1 = np.array( object: [0, lower_sat, lower_val], dtype=np.uint8)
        upper1 = np.array( object: [10, upper_sat, upper_val], dtype=np.uint8)

        lower2 = np.array( object: [170, lower_sat, lower_val], dtype=np.uint8)
        upper2 = np.array( object: [180, upper_sat, upper_val], dtype=np.uint8)

        return (lower1, upper1), (lower2, upper2)  # Return two ranges for red

    # Standard hue range for other colors
    lowerLimit = np.array( object: [max(hue - 10, 0), lower_sat, lower_val], dtype=np.uint8)
    upperLimit = np.array( object: [min(hue + 10, 180), upper_sat, upper_val], dtype=np.uint8)

    return lowerLimit, upperLimit
```

Figure 6.0: Util file Py code that need to import for BGR to HSV conversion

3. **Colour Masking:** identify and isolate objects of specific colours from a webcam feed. The Figure 7.0 below show the colour masking process

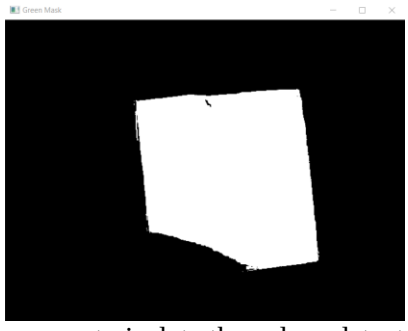


Figure 7.0: Colour masking process to isolate the colour detected based on BGR colour code to convert into HSV colour format

4. **Contour detection & Bounding box:** Find the contour from the color mask. Then, highlighting the detected object so the user can see where the object by using rectangle bound. The rectangle bound is labelled with colour detected. Figure 8.0 shows the detected object colour in real time camera.

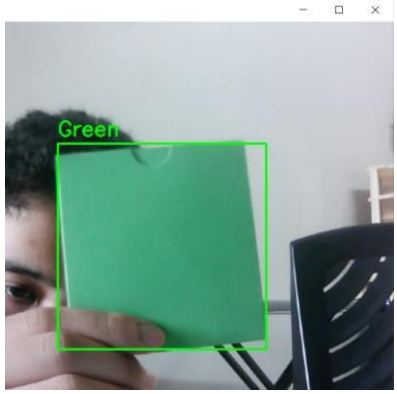


Figure 8.0: Detected & labelled object inside bounding box in real time camera

2.2 Software

1. PyCharm

PyCharm (Figure 9.0) is a widely used integrated development environment (IDE) for writing Python code, designed to simplify coding through a variety of helpful features. It offers intelligent code suggestions that predict what the user is typing, enabling faster development and reducing the likelihood of errors. PyCharm also includes powerful debugging tools to help identify and fix issues efficiently. Additionally, it supports web development and integrates well with popular frameworks such as Django and Flask. These capabilities make PyCharm a preferred choice for both beginners and experienced Python developers (Van Horn & Nguyen, 2023).

Figure 9.0: PyCharm software

3.0 RESULTS AND DISCUSSION

Data collection of this project is to analyze how sensitive the coloured object exposed to the colour detection project. Here the coloured object successfully detected in Figure 10.0(a), Figure 11.0(b) & Figure 12.0(c).

Three different colour of cloths pin are pinned together (refer in Figure 13.0) on the ruler to make sure the time taken for these three objects running simultaneously. There are two types of data analysis for this project such as distribution of object size (average area) for each colour and total detections per colour.

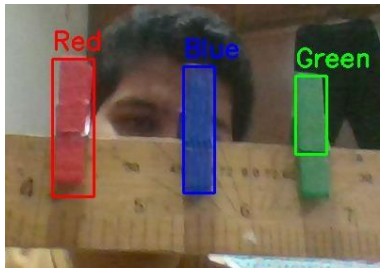


Figure 13.0: Red cloths pin, blue cloths pin and red cloths pin are pinned together on the ruler

Environmental lighting becomes the factor why the colour is not successfully detected as in Figure 14.0 and Figure 15.0

Figure 14.0: Colour is not detected due to low lighting

Figure 15.0: Colour is detected with proper lighting condition (table lamp on)

3.1 Tables and Figures

When coloured objects are identified in a frame, the program logs a new entry containing the timestamp (marking the moment of detection), the detected colour group, the number of objects found, and their average area. This data is then saved into a CSV file named color_detection_log.csv. After that, file in excel format is created with structure of the data: "Timestamp", "Colour", "Object Count", and "Avg Area". The data is compiled as in **Table 2.0.**

Table 2.0: data consist of colour, object count & Avg area (px²) during real time detection

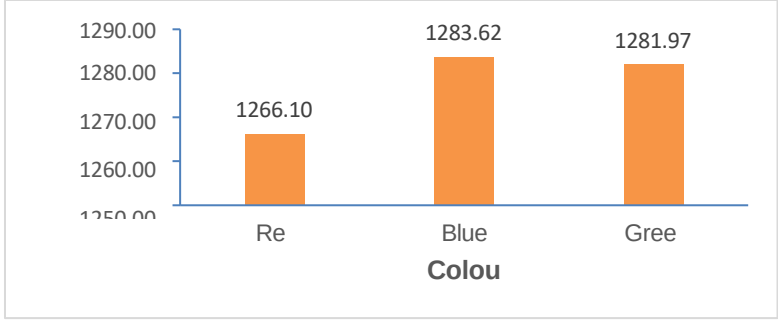
Object	Object count	Avg area(px²)
Red	417	12266.10
Green	924	1283.62
Blue	937	1281.97

As in Table 2.0, each object detected in the video frame is analyzed using image processing techniques, where the detected objects are differentiated based on their color grouping Red, Green, and Blue. For each frame processed, two primary parameters are recorded simultaneously: the **object count** and the **average area** of the objects.

The **area** is measured in **square pixels (px²)**, which refers to the number of pixels that make up the surface of a detected object in the frame. This gives an indication of the **size** of the object as perceived in the image. A higher value in px² represents a **larger object**, whereas a lower value indicates a **smaller object**.

At the same moment that objects are detected and counted, their corresponding areas are calculated. The system then computes the **average area (in px²)** for all objects of a specific color detected in that frame. Therefore, the **object count,** and **average area** are captured **simultaneously**, ensuring a fair and consistent analysis across all color groups. This synchronous data logging allows for reliable comparison between the **frequency** and **relative size** of colored objects detected throughout the video stream

The Figure 16.0 illustrate a graph of the **average area (in px²)** of objects detected based on colour. Among the three colours analysed Red, Blue, and Green the **red objects recorded the smallest average area**, with a value of **1266.10 px²**. In contrast, **Blue and Green objects exhibited slightly larger average areas**, measured at **1283.62 px²** and **1281.97 px²** respectively. This indicates that objects detected in blue and green hues tend to occupy a marginally larger space compared to those detected in Red. Figure 4.6 below shows the average area(px²) vs colour



The Figure 17.0 presents the **object count** corresponding to each colour. It shows that **Red objects appeared the least frequently**, with a total count of **417**. On the other hand, **blue and**

green objects were detected in much higher numbers, with **924** and **937** counts respectively. This suggests that objects associated with the blue and green colours were not only more common in the dataset but also had a higher occurrence rate compared to Red.

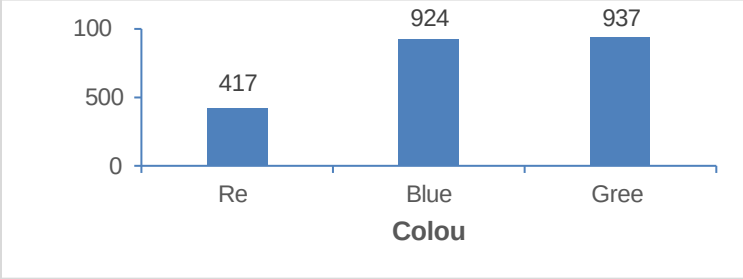


Figure 17.0: Graph Bar chart shows the object count vs Colour.

4.0 CONCLUSION

The analysis of object detection based on colour shows that green and blue objects consistently have larger average areas and higher detection counts compared to red objects. Specifically, although the differences in average area between the three colours are minor, the frequency of detection reveals significant variation red objects appear far less frequently. This suggests that the system performs better at detecting and isolating green and blue objects, possibly due to better contrast or lighting sensitivity in the HSV colour space.

These findings highlight the importance of optimising colour segmentation techniques particularly for red, which appears less prominent in both area and count. For users with Colour Vision Deficiency (CVD), such insights are valuable in improving the reliability of the system in distinguishing all primary colours effectively. Enhancing red colour detection will ensure better inclusivity and accuracy, ultimately strengthening the system's role as an assistive tool for the colour-blind community.

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A Heuristic Approach to Head Gesture Recognition for Mobility Assistance in Wheelchairs

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ABSTRACT

Around 10% of the world's population-about 650 million people-live with physical disabilities, and many depend on wheelchairs to move around. For those with limited or impaired upper limb function, traditional wheelchair controls like manual or joystick systems can be extremely difficult. Manual wheelchairs typically need a lot of physical strength that may not be available to people with mobility impairments. Even motorized wheelchairs with joystick control need precise movements, which may also be difficult to do for people with more severe movement impairments. This study proposes a handcrafted head gesture recognition-based wheelchair control system as a hands-free and accessible mobility solution to counteract these limitations. To develop a head movement-controlled mechanism, allowing for the wheelchair operation to maintain a reliable and steady function for users with severe motor impairments. It employs an Arduino uno as a microcontroller, 3V-6V DC motor and Osoyoo motor shield L293DD motor driver shield. In software, gesture detection logic is implemented in PyCharm, and motor controls are programmed using Arduino IDE. It detects five predefined head gestures (left, right, up, down and forward). Head gesture detection accuracy is quantified by evaluating Z and Y rotational angles relative to defined thresholds in different lighting conditions. This innovative method would also enhance the life independence of people with physical disabilities, by offering a practical, affordable and non-invasive assistive mobility solution.

Keywords: Wheelchair, Handcrafted, Physical Disability, Head Gesture and Mobility Aid.

1.0 INTRODUCTION

Statistics show us that 43 million are disabled, about 52% of spinal cord injured individuals are considered paraplegic and 47% quadriplegic (Patil, 2020). Quadriplegia, or tetraplegia, is defined as the condition characterized by weakness in all four limbs and usually occurs due to upper motor neuron injuries, although it may sometimes happen due to lower motor neuron problems (Zedde et al., 2022). For people with quadriplegia, controlling multiple devices for daily activities is difficult due to limited range of motion, demonstrating the need for accessible, integrated technologies that enhance independence and are easy to implement daily (Orejuela-Zapata et al., 2019). Wheelchairs in fact serve with functional use and improve an individual's quality of life with that kind of mobility impairment (Callejas-Cuervo et al., 2020).

Standard mobility devices like manual or electric wheelchairs are often unsuitable for individuals with severe paralysis due to insufficient strength to operate the joystick through its full range of motion (Maskeliunas & Simutis, 2019). Research shows that joystick control in electric wheelchairs has been challenging for roughly 41% of users. Such a situation is vital for individuals who have complete paralysis in the arms or limbs, like quadriplegic patients, since they are unable to have any form of finger movement (Bhuyain et al., 2019). This paper proposes the design of a head gesture-controlled wheelchair system that relies entirely on handcrafted rules for gesture detection. By utilizing head pose recognition and experimentally optimized threshold values for directional commands, the system offers a reliable, hands-free mobility solution for individuals with quadriplegia. It enables wheelchair control through natural head movements without the need for complex training data.

1.1 Quadriplegia

Quadriplegia is a state where an individual suffers from an inability to use their legs fully and has limited or no hand function. It happens due to a defect in the brain or in the spinal cord originating from the cervical (neck) region; thus, affecting the upper motor neuronal pathways. It is more uncommon that quadriplegia has resulted from lesions of lower motor neurons, close to the muscles that they control. Diagnosing the specific cause of sudden quadriplegia, without injury, presents difficulties since many conditions can be responsible for it. Quadriplegia may result, in some cases, from spinal cord injury, especially in case where blood supply to the spinal cord is cut off causing spinal cord ischemia. This kind of damage generally affects certain nerve pathways in the neck and upper back, causing both upper and lower motor neuron symptoms (Zedde et al., 2022). Independent mobility is crucial for improving quality of life, encouraging self-reliance, and bolstering mental health in people with quadriplegia (Malik et al., 2019).

1.2 Non-Intrusive Head Movement Control for Powered Wheelchairs

YOLOv3 enhances object detection by utilizing multi-scale feature maps and refining its backbone network. The network uses nine anchor boxes derived via K-means clustering, distributed evenly across the three scales. Additionally, YOLOv3 incorporates a residual network structure to improve feature extraction efficiency and accuracy (Jiang et al., 2022).

Chatzidimitriadis et al. (2023) has proposed a joystick that can be controlled using head movements. It is head movement. It uses an RGB camera and detects the use of the YOLOv3 network head. If the head moves up it means forward, If the head moves down it means backwards, If the head moves right, it means turn right, If the head moves left, it means turn left. A vision-based, non-intrusive, cost-efficient system for controlling a wheelchair via head movements, only relying on a simple web camera. It designed a system that robustly performs head detection and head pose estimation, improving upon similar existing methods by combining a state-of-the-art neural network and a fast and accurate head landmark detector. Figure 1 shows the example head movement control by using the electric wheelchair.

Figure 1: Electrical wheelchair
Source: https://doi.org/10.1109/ACCESS.2023.3275529

1.3 Head Movement Control of Powered Wheelchair

OpenCV is a widely used open-source computer vision library capable of recognizing objects, faces, and even handwritten text in images and video streams. It plays a critical role in object detection tasks, which intersect with machine learning, signal processing, and big data, by enabling feature identification in visual data (Kavitha et al., 2021).

Solea et al. (2019) has proposed command movement as left, right, forward, backward and stop commands (when the user closes his eyes). It used a manual wheelchair. It has head movement and face detection using OpenCV. To control the powered wheelchair, in this paper, a two block structure is proposed. The first block, called the OpenCV Domain is responsible for data acquisition and processing, and it sends to the second block of the structure, called the Motor

Control Domain, the ratio to generate the DC motor movement. In the initial version of this control structure, the commands were generated using the video camera frame centre as the reference point but the weak point in this case was the synthesis of the stop command. Figure 2 shows the example head movement control by using the manual wheelchair.

Figure 2: Manual wheelchair
Source: https://doi.org/10.1109/icstcc.2019.8885844

1.4 Head-Motion Controlled Wheelchair

Prasad et al. (2019) has proposed system uses an accelerometer to detect head tilts. The accelerometer, which is attached to a headgear or hat, senses the head's position and sends this data to a microcontroller. The microcontroller sends the data wirelessly to a receiver on the wheelchair's frame. Once received, the data is processed to control the wheelchair's motors. The motor driver then activates the motors to move the wheelchair forward or backward based on the head's tilt direction. Figure 3 shows the example of head movement control by using the prototype wheelchair. The L293D motor driver is used to control how the motors move and how fast they spin. Setting the "enable" pin to HIGH lets the motor run at full speed, while setting it to LOW slows it down. For instance, if the left motor's enable pin is set to HIGH, and input 1 is HIGH while input 2 is LOW, the motor will rotate clockwise.

Figure 3: Prototype wheelchair
Source: https://doi.org/10.1109/rteict.2017.8256876

1.5 Handcrafted

Reddy et al. (2020) proposed traditional methods primarily depend on hand-crafted features like Histogram of Oriented Gradients (HOG), Local Binary Patterns (LBP), 3D-Gradients, and Local Phase Quantization (LPQ), often extracted from key facial regions such as the eyes, nose, and mouth. These features are commonly fed into classifiers like Multi-Layer Perceptron's (MLPs) for expression classification. Infrared imaging and facial landmark-based approaches have also gained popularity, with landmark movements effectively representing specific expressions.

Handcrafted methods in computer vision refer to techniques that have been completely hand designed, and handpicked for features or landmarks points in images, as opposed to utilizing methods that learned features from the data as machine learning approaches do. These methods involve the use of algorithms such as decision trees and SVMs which look for key points to detect and match based on decisions taken using hand rules and measurements. While the handcrafted methods generally utilize features and landmarks that are defined by an operator, note that X, Y, Z (in the context of X, Y, Z coordinates in 2D or 3D space). These landmarks positions can be considered as a point in the image and would use the hand rules or algorithms to detect, describe and match features. While machine learning approaches do their learning based on patterns found within the data, handcrafted methods tend to make their decisions based on hand designated methods like mathematically determined score and thresholds that relate to some points or regions of interest in X, Y, Z position, intensity, gradients, or textures (Ma et al., 2020).

2.0 METHODOLOGY

2.1 Block Diagram of Head Movement Recognition System

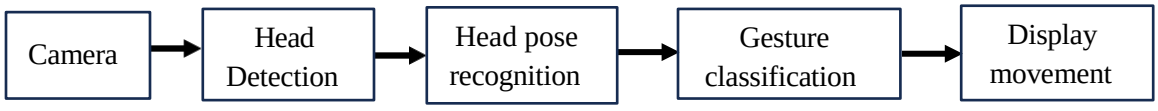

Figure 4: Head movement using handcrafted

Figure 4 shows head movement-based wheelchair control system using handcrafted approach. All the operations begin with capturing and visualizing real-time video of the user, Media pipe performs head detection by localizing the facial region in each frame. Once the head is detected, pose recognition is employed to extract the head's 2D orientation by computing the rotation angles of tilt, twist, and shake about the Z and Y axes, respectively. Perpendicular to each axis are "yaw" and "pitch". These angle values are used as handcrafted features for gesture classification wherein specific head movement is recognized as per the rule-made thresholds. A classified gesture then generates a corresponding command and displays it visually. The defined command is then used to navigate the wheelchair henceforth allowing the hands-free movement of the user.

2.2 Hardware System Block Diagram

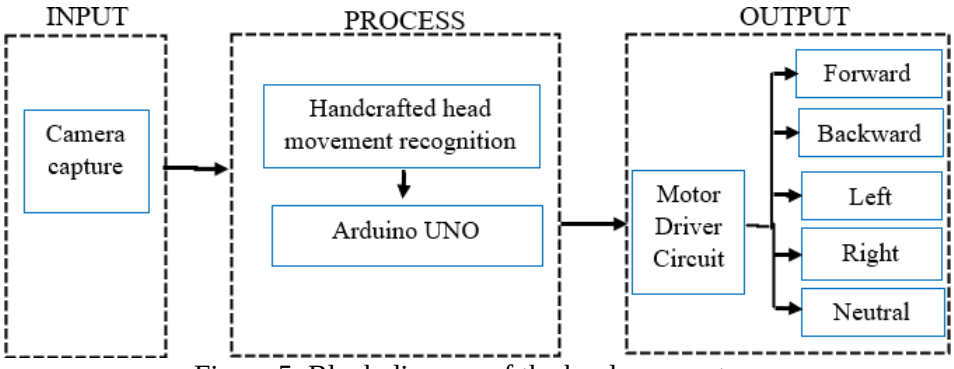

Figure 5: Block diagram of the hardware system

Figure 5 shows block diagram of the hardware system. This block diagram represents system for a wheelchair starting with input from a camera that records real-time head movements, such as head up, down, turn right, turn left and head forward. The raw data are passed through the data

processing unit and interpreted by handcrafted head movement recognition. That is, it is a handcrafted method which looks at the head's angular orientation strictly according to predefined thresholds to classify gestures. The controller, which consists of an Arduino Uno, receives these commands, processes them, and sends them to motor control commands, interfacing with the motor driver circuit to ensure proper motor operation. Output is the movement of the motor. Next, the user need to perform head movement if head up moves the motor forward, if head down moves the motor backward, if head turn right the motor will turn right, if head turn left the motor will turn left and if head forward the motor will neutral.

2.3 Flowchart

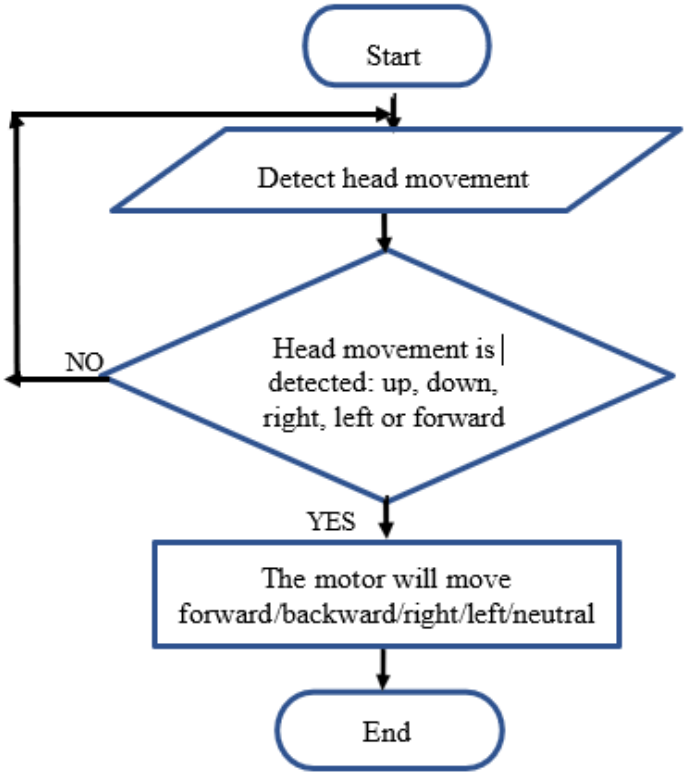

Figure 6: Flowchart

In Figure 6 show the project flowchart. Initially, the system detects head movements, and the motor responds based on the classified direction.

2.4 Software

The software used in this project includes PyCharm and the Arduino IDE. PyCharm is used to develop the heuristic approach code, while the Arduino IDE is used to program the motor control system. The Serial library is utilized to establish serial communication between the Python code in PyCharm and the Arduino code.

2.5 Hardware

The hardware used in this project includes an Arduino UNO microcontroller, an Osoyoo L293DD motor driver shield, 3V–6V DC motors, a 9V battery, two wheels, and a ball caster wheel. The wheelchair body is constructed from durable acrylic material to provide a stable base for all components. Figure 7 shows the completed prototype of the wheelchair system.

Figure 7: Completed design of the prototype wheelchair

3.0 RESULTS AND DISCUSSION

Data collection was conducted to evaluate the accuracy of head movement detection under varying lighting conditions. The experiment involved Subject A and utilized a handcrafted detection method that recognizes head movements based solely on variations in Z and Y angles. The testing of the system was done considering five different threshold values. The subject was made to do some head movements while observing three lighting conditions at a specified location, keeping the distance constant at 30 cm from the camera. The aim was to compare the detection accuracy from the three lighting setups versus five threshold values tabulated in Table 1. Results were collected for analysis.

3.1 Head Movement Detection Output Under Different Lighting Conditions Figure 8 shows the three lighting conditions used in the experiment: (a) Dim, (b) Normal, and (c) Bright. Based on figure, the right section of the output, displays head movement detection using 468 facial landmarks, including a reference line from the nose tip. The left section presents a graphical user interface (GUI) that shows directional indicators corresponding to wheelchair navigation. The user performed head movements under each of the three lighting conditions as shown.

(a)

(b)

(c)

Figure 8: Output results under three lighting conditions as (a) Dim, (b) Normal and (c) Bright

3.2 Head Pose Analysis and Accuracy Results

The subject was seated 30 cm away from the camera. The system's accuracy was evaluated across five different threshold values under three lighting conditions. The results demonstrate

that the system can accurately detect head movements despite variations in lighting. Figure 9 shows the angle that defines the rotation matrix R that represents the orientation of the head. Table 1 shows the recorded accuracy of head movement detection at different Z and Y thresholds under varying lighting conditions.

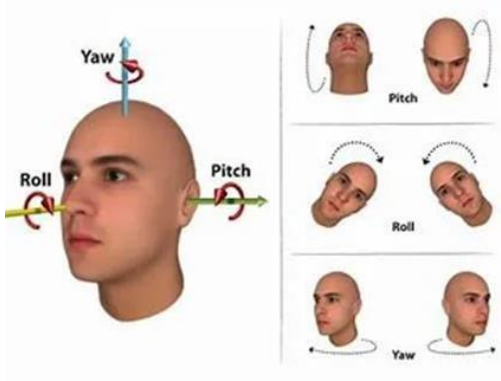

Figure 9: The orientation of the head

Source: https://medium.com/@abhishekjainindore24/different-ways-to-calculate-head-pose estimation-ypr-yaw-pitch-and-roll-c3542bac03dc

Table 1: Head Movement Detection Accuracy at Different Z and Y Thresholds Under Varying Lighting Conditions on a White Background

Lighting Condition	Head Pose/Accuracy									
	Head Up	Accuracy (%)	Head Down	Accuracy (%)	Head Turn Right	Accuracy (%)	Head Turn Left	Accuracy (%)	Head Forward	Accuracy (%)
DIM	Z>1, Y>0	93.28	Z<-1, Y>0	90.97	Z>0, Y>1	91.75	Z>0, Y<-1	91.42		91.87
	Z>2, Y>0	89.92	Z<-2, Y>0	90.21	Z>0, Y>2	90.79	Z>0, Y<-2	89.55		89.63
	Z>3, Y>0	90.58	Z<-3, Y>0	88.84	Z>0, Y>3	91.42	Z>0, Y<-3	91.05	Z:0, Y:0	90.82
	Z>4, Y>0	89.97	Z<-4, Y>0	89.93	Z>0, Y>4	88.76	Z>0, Y<-4	89.71		91.74
	Z>5, Y>0	93.82	Z<-5, Y>0	91.45	Z>0, Y>5	92.67	Z>0, Y<-5	91.68		92.87
NORMAL	Z>1, Y>0	94.41	Z<-1, Y>0	93.59	Z>0, Y>1	93.77	Z>0, Y<-1	92.94		93.75
	Z>2, Y>0	91.36	Z<-2, Y>0	91.75	Z>0, Y>2	93.53	Z>0, Y<-2	91.86		91.54
	Z>3, Y>0	92.38	Z<-3, Y>0	90.67	Z>0, Y>3	93.51	Z>0, Y<-3	92.87	Z:0, Y:0	92.96
	Z>4, Y>0	91.73	Z<-4, Y>0	91.23	Z>0, Y>4	90.88	Z>0, Y<-4	91.19		93.92
	Z>5, Y>0	96.56	Z<-5, Y>0	94.88	Z>0, Y>5	93.93	Z>0, Y<-5	94.86		94.03
BRIGHT	Z>1, Y>0	95.78	Z<-1, Y>0	95.15	Z>0, Y>1	95.81	Z>0, Y<-1	95.75		95.69
	Z>2, Y>0	92.81	Z<-2, Y>0	93.71	Z>0, Y>2	96.84	Z>0, Y<-2	92.68		92.73
	Z>3, Y>0	93.47	Z<-3, Y>0	91.94	Z>0, Y>3	94.81	Z>0, Y<-3	94.92	Z:0, Y:0	93.85
	Z>4, Y>0	93.66	Z<-4, Y>0	92.77	Z>0, Y>4	92.34	Z>0, Y<-4	93.62		94.85
	Z>5, Y>0	96.69	Z<-5, Y>0	95.68	Z>0, Y>5	95.96	Z>0, Y<-5	96.71		95.97

Figure 9 shows the head pose using three rotation angles. Roll refers to rotation along the X axis, which corresponds to tilting the head to the left or right. Pitch refers to rotation along the Y-axis, representing head movements such as looking up or down. Yaw refers to rotation along the Z-axis, corresponding to turning the head to the left or right (Jain, 2025).

Table 1 shows the recorded accuracy values for detecting each head pos (up, down, turn right, turn left, and forward) for under different threshold settings and lighting conditions. The accuracy of head movement recognition was evaluated by testing multiple threshold values along the Z and Y axes, with thresholds ranging from 1 to 5. Since the system relies on a handcrafted, rule-based classification method, these axis thresholds were experimentally selected to determine which combinations provided the most accurate results. To identify the optimal parameters, the system was tested under three different lighting conditions which are dim, normal, and bright. For each condition, five different threshold configurations were tested.

The Z and Y axis values that consistently achieved the highest accuracy across these lighting scenarios were chosen as the final thresholds for the head gesture recognition system.

4.0 CONCLUSION

In conclusion, a head gesture-controlled wheelchair system was successfully designed using a handcrafted, rule-based approach to interpret head movements for directional control. The system integrates a head movement-based control mechanism that demonstrated consistent operation across varying lighting conditions, ensuring reliable usability for individuals requiring mobility assistance. Through extensive testing of multiple Z and Y axis threshold configurations, the system achieved high recognition accuracy for head gestures corresponding to forward, up, down, left, and right movements. This validates the effectiveness of the developed system in accurately detecting head gestures and supporting responsive, real-time wheelchair navigation, thereby fulfilling the project's objectives. This system provides the added benefit of allowing users to practice and operate from their own home environment. The design of the device is a prototype that test the performance of the developed system in different lighting environments. The project tested a head movement control to provide consistent and reliable wheelchair operation.

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Autonomous Portable Oxygen Tank For COPD Patient

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ABSTRACT

Chronic Obstructive Pulmonary Disease (COPD) significantly impairs patients' mobility and quality of life due to the necessity of managing heavy oxygen tanks required for long-term oxygen therapy. This project proposes the development of an autonomous portable oxygen tank for COPD patient, aims to reducing the physical burden on COPD patients and enhancing their independences. The robot utilizes an Arduino-based system with integrated ultrasonic sensors and motorized wheels, connectivity for efficient patient-following and obstacle avoidance. This innovative solution addresses critical challenges, including the physical strain of carrying oxygen tanks and adaptability to varied environments, providing an improvement in mobility and daily functionality for COPD patients. The project's approach combines existing oxygen tank carrying equipment with robotic technology that can follow the subject's movements.

Keywords: Chronic Obstructive Pulmonary Disease (COPD), Human-Following Robot, Assistive Technology

1.0 INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory disorder characterized by airflow limitation that affects millions of people worldwide (Agustí et al. 2023). Patients with severe COPD often require supplemental oxygen therapy to maintain adequate blood oxygen levels and improve their quality of life (QoL) (Miravitlles and Ribera 2017). The disease represents a substantial economic and social burden globally, with patients facing significant challenges in performing daily activities due to breathing difficulties (Romain A Pauwels 2004). Traditional oxygen delivery systems rely on heavy aluminium or steel tanks that create mobility limitations for patients (Almutairi et al. 2018). These conventional tanks are cumbersome to transport, forcing patients to restrict their movements and reducing their independence (Jacobs et al. 2020). While portable oxygen concentrators exist, they often prove insufficient for patients requiring higher flow rates (Hardavella et al. 2019). This limitation significantly impacts patient adherence to prescribed oxygen therapy regimens, which typically recommend usage for 15-16 hours daily for optimal benefits (Hardinge et al. 2015).

Innovative solutions to mobility issues have been made possible by recent developments in assistive technology. Autonomous systems and robotics have shown particular promise in healthcare applications, including patient support and rehabilitation (Pandey and Gelin 2018). Human-following robotic systems, equipped with advanced sensor arrays, demonstrate the potential to transform how patients interact with medical equipment (Uguzlar et al. 2023). These technologies utilize ultrasonic sensors and microcontroller units to track human movement accurately while maintaining safe distances (Tai et al. 2019).

This study addresses three critical challenges in current oxygen therapy management: First, the physical burden of transporting heavy oxygen tanks (Almutairi et al. 2018). Second, the lack of automated systems to assist with oxygen tank mobility (Sanchez-Morillo, Fernandez-Granero, and Leon-Jimenez 2016). Lastly, tracking distance error and heading angle difference between the human and robot in different scenarios (Uguzlar et al. 2023). The solution combines the reliability of standard E-type oxygen cylinders (King, Houseman, and Decker 2018) with an autonomous trolley system featuring:

1. A motorized platform with 12V battery support for stable operation
2. An array of ultrasonic sensors for precise human tracking
3. Advance obstacle avoidance capabilities for safe navigation
4. Optimized control algorithms for smooth movement

The system is designed specifically for use on flat surfaces such as indoor environments and designated disabled pathways (Xia et al. 2023).

2.0 MATERIAL AND METHOD

As a technological solution for medical communities, the autonomous portable oxygen tank will go through rounds of testing and modifications. This project plan to develop the portable device by retrofitting the current oxygen trolley with a human-tracking robot system for automated mobility control.

2.1 PROJECT DESIGN

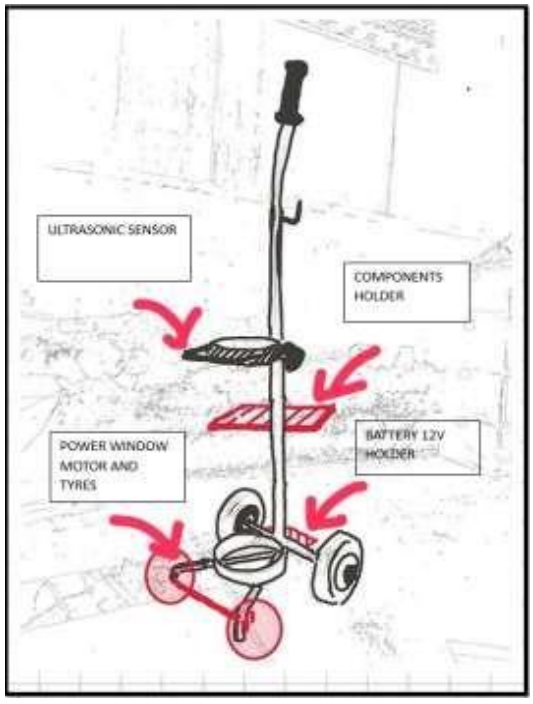

Figure 1: Project design sketch

Figure 1 shows design sketch for an autonomous robot oxygen tank. The trolley is designed to facilitate and accommodate the cylinder-shaped oxygen tank and the shaded red area is the additional parts added to the trolley to accommodate components, 12V battery holder and power window motor combined with tires. An ultrasonic sensor also be placed in front of the trolley to detect patient movement.

2.2 Block Diagram

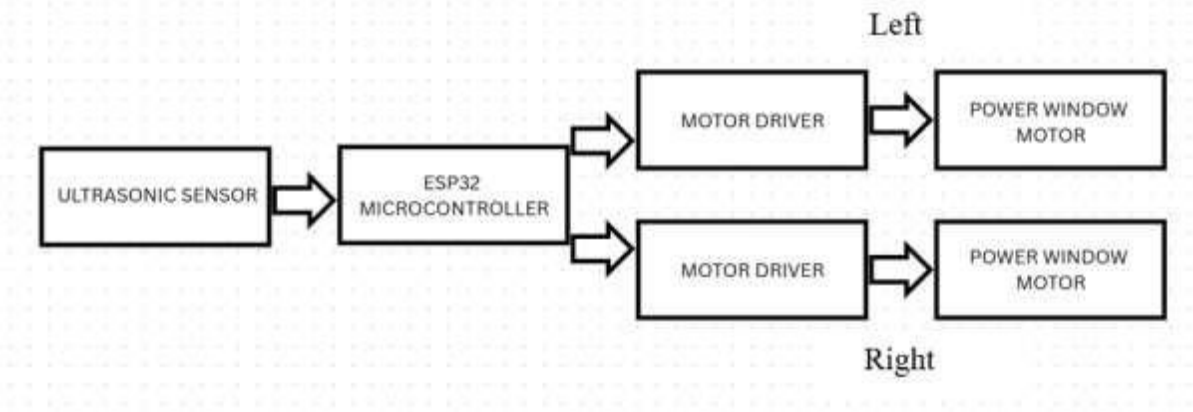

Figure 2: Block diagram

As shown in figure 2 this outlines a system which an ultrasonic sensor uses to detects objects or measures distances and sends this data to an ESP32 microcontroller. The ESP32 processes the information and directs the motor driver to control a power window motor. Essentially, the sensor's input triggers the microcontroller to manage the motor's actions, enabling automated operation of the power window based on the sensor's readings. This setup demonstrates a practical application of sensor-based automation used in this project.

Table 1 Autonomous Oxygen Trolley System Hardware Components

COMPONENT	FUNCTION
ESP32-WROOM-32D (with Expansion Board)	Main microcontroller with dual core 240MHz processor, 520KB SRAM, 4MB Flash. Built-in Wi-Fi/Bluetooth for wireless communication and IoT capabilities. Expansion board provides easy GPIO access and power regulation
HC-SR04 Ultrasonic Sensors (3x)	Array of distance measurement sensors (2cm-400cm range) for 360° human tracking and obstacle detection. Operates at 5V with 15° detection angle.
30A DC Motor Driver (2x)	High-current H-bridge driver for 12V motors (30A peak). Includes over-current, over-temperature, and short-circuit protection. PWM- controlled via ESP32.
12V 10Ah Battery	Powers motors and electronics. 10A continuous discharge supports 30A driver peaks.
Automotive Power Window Motors (x2)	High torque 12V DC built-in gearboxes. Waterproof design for outdoor use. Encoder feedback for position control.
Voltage Regulator (LM7805)	Converts 12V battery power to stable 5V supply for sensitive electronic components.

2.3 Schematic Diagram

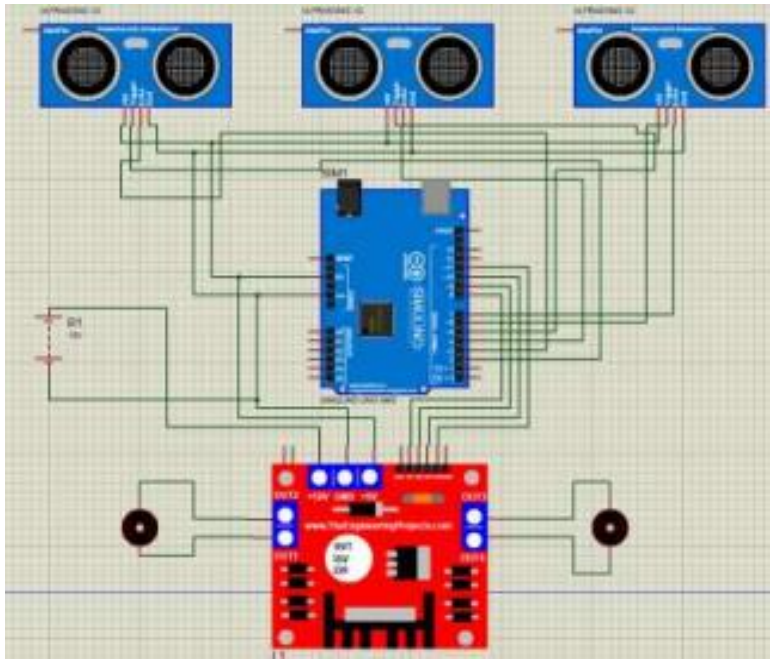

Figure 2: Circuit simulation

As shown in Figure 2 integrates ultrasonic sensor with a microcontroller used to create a system capable of detecting objects or measuring distances. The three ultrasonic sensors in this system serve critical functions for patient tracking and obstacle avoidance. These components are providing comprehensive spatial awareness, one sensor faces forward for primary tracking of the patient's position, while two angled sensors monitor lateral movements and environmental obstacles. This triple-sensor design achieves tracking accuracy and can predict directional changes by analysing relative distance patterns across all three units. The microcontroller processes the sensor data and controls multiple output ports, which can interface with various external devices operating at different voltage levels 12V. This setup is likely used in applications requiring precise control and automation, such as robotics, industrial machinery, or smart systems.

2.4 Software

Figure 3: Arduino IDE

Figure 3 show the Arduino IDE (Integrated Development Environment) is an open-source, user-friendly software platform designed for writing, compiling, and uploading code to Arduino-compatible boards, such as the ESP32 microcontroller. During development, the IDE is used to build and verify the code before deployment. The primary function of this code is to control and coordinate the system's hardware components. Once the programming is complete, the finalized code will be uploaded to the ESP32, which serves as the central microcontroller for the system.

3.0 RESULT

3.1 Complete project

Figure 4: Autonomous Portable Oxygen Tank

Figure 4 shows the complete setup of the Autonomous Portable Oxygen Tank designed to assist COPD patients in carrying their oxygen supply with minimal physical effort. The system integrates a securely mounted oxygen cylinder on a mobile trolley equipped with wheels, a power window motor for movement, and an ESP32-based control unit. Ultrasonic sensors are installed to detect the patient's position and guide the trolley accordingly. The electrical components, including the battery and motor drivers, are housed on the frame, with wiring neatly arranged for functionality and safety. This fully assembled prototype demonstrates the practical implementation of an assistive, smart mobility solution for improved patient independence.

3.2 Data analysis

This section focuses on evaluating the performance and reliability of the autonomous oxygen trolley system based on experimental results. Key parameters such as patient-tracking distance, sensor angle accuracy, are measured and analyzed. The data collected through sensors and the Blynk platform is used to assess how effectively the system follows the patient and maintains operational stability. This analysis helps validate the system's design objectives, identify potential improvements, and ensure its suitability for real-world application in supporting COPD patients.

Position between ultrasonic sensors

Distance between ultrasonic		1cm			4cm			8cm		
Movement	Test	Left	Front	Right	Left	Front	Right	Left	Front	Right
Forward	1	/	/	/	/	/			/	
	2	/	/	/	/	/			/	
	3	/	/	/		/	/		/	
Right	1	/	/	/		/	/		/	/
	2	/	/	/		/	/		/	/
	3	/	/	/	/	/			/	/
Left	1	/	/	/	/	/		/	/	
	2	/	/	/	/	/		/	/	
	3	/	/	/		/	/	/	/	

Table 2: Testing position distance between ultrasonic sensors

Table 2 shows the experiments that have been conducted on the positions between the ultrasonic sensors. The positions studied are at 1cm, 4cm and 8 cm. This experiment was conducted 3 times for each movement. As shown in the table, a 1cm positioning distance between ultrasonics indicates that all ultrasonics detect the patient/object in front in each direction of movement. This is because, ultrasonic positions that are too close to each other cause movement confusion that is intended. While at a distance of 4 cm, it shows unstable detection from ultrasonics. As can be seen in the table, especially in forward movement where only the ultrasonic in the middle should detect, but the left and right sensors also detect the patient in front. Although the detection on all three sensors does not occur simultaneously like the 1cm position, the tires movement confusion is still the same.

Next, at a distance of 8 cm, it shows the level of sensor detection in a stable state. As can be seen in the table, the movement of the trolley in front shows the detection of only the ultrasonic in the middle only makes the detection. While the movement to the left and right also shows the stability in making the detection of the patient in front. This makes the movement of the tire able to follow the movement of the patient in front without any movement confusion. This also complies with the instructions that have been set in the coding in the sensor to make the detection which makes the movement of the power window motor and tire.

Distance between trolley and patient

Table 3: Estimated system behaviours

Distance between Patient and trolley (cm)	Expected Behaviours
29<	Stop (too close)
30–80	Turning Direction / Move Forward
>81	Stop (too far)

Table 3 show the system uses distance measurements between the patient and the trolley to determine how it should behave. If the distance is less than 30 cm, the trolley stops because it is too close to the patient, avoiding collision or discomfort. When the distance is between 30 cm and 80 cm, the trolley moves forward or adjusts its direction to follow the patient properly. If the distance exceeds 81 cm, the trolley stops again, as the patient is too far ahead, and the

system needs to wait until the patient comes within the ideal range. This behaviour ensures safety and efficient movement during operation.

Table 4: Result from demonstration

Test	Actual Distance (cm)	Interpreted Behaviour	Correct behaviours?
1	25	Stop	Yes
2	30	May stop or move	Unstable
3	32	Move Forward	Yes
4	40	Move Forward	Yes
5	55	Move Forward	Yes
6	70	Move Forward	Yes
7	80	May stop or move	Unstable
8	82	Stop	Yes
9	90	Stop	Yes

Table 4 shows the trolley was tested under nine different distance scenarios to evaluate its ability to interpret and respond according to the expected behaviours logic: stop when too close (<30 cm), follow when within range (30– 80 cm), and stop when too far (>80 cm). The results are summarized in the table, comparing actual distances, interpreted behaviours, and whether the system responded correctly.

In Test 1, where the distance was 25 cm, the trolley correctly stopped, preventing it from getting too close to the patient. This confirms the safety feature at short distances. Test 2, with a reading of exactly 30 cm, showed unstable behaviours as the trolley was at the boundary between stopping and moving. Similarly, in Test 7 at exactly 80 cm, instability was also observed, indicating that boundary values may need more refined control logic.
Tests 3 to 6, covering distances from 32 cm to 70 cm, demonstrated correct and stable forward movement, aligning well with the expected "Move Forward" behaviours in the safe range (30–80 cm). These tests show that the system is effective in tracking the patient when they are within the optimal range.

In Tests 8 and 9, where distances exceeded 80 cm (82 cm and 90 cm), the trolley successfully stopped, recognizing that the patient had moved too far ahead and preventing the trolley from following beyond its designed limit.

Out of the 9 tests, 7 tests (78%) showed behaviours that matched the expected design, indicating reliable performance under most conditions. The two instances of unstable behaviours at the boundary values (Tests 2 and 7) highlight an area for improvement in system calibration. Overall, the demonstration validates that the autonomous trolley system functions accurately in controlled settings, with consistent behaviours in most distance scenarios, ensuring both safety and usability.

4.0 DISCUSSION

The development of the autonomous portable oxygen tank for COPD patients represents a significant step forward in addressing the mobility challenges faced by individuals requiring long-term oxygen therapy. Traditional oxygen delivery systems, which rely on heavy and

cumbersome tanks, often restrict patient movement and reduce independence, leading to lower adherence to prescribed therapy regimens. This project tackles these issues by integrating robotic technology with standard oxygen trolleys, creating a system that autonomously follows patients while avoiding obstacles. The use of ultrasonic sensors for human tracking and navigation ensures that the trolley maintains an optimal distance from the patient, reducing the physical effort required to transport oxygen tanks manually.

The experimental results highlight the system's effectiveness in controlled environments, with successful patient tracking at distances ranging from 0.3m to 1.5m. The trolley demonstrated reliable performance in both straight line movement and turning scenarios, indicating its adaptability to different walking patterns. However, challenges such as sensor limitations in highly dynamic or crowded environments were observed. For instance, ultrasonic sensors may struggle with detecting transparent or irregularly shaped obstacles, which could affect navigation accuracy. Additionally, the current design is optimized for flat indoor surfaces, limiting its immediate applicability in uneven or outdoor settings. Future iterations could incorporate additional sensor types, such as LiDAR or infrared, to enhance environmental perception and robustness.

Another critical consideration is power management. While the 12V battery provides sufficient energy for short term operation, prolonged use may require more efficient power solutions or swappable battery systems to ensure uninterrupted functionality. The motorized wheels and control algorithms performed well in maintaining smooth movement, but further optimization could reduce energy consumption and improve response times during sudden directional changes.

Beyond technical performance, the system's usability and patient acceptance are vital for real-world adoption. The trolley's design prioritizes simplicity and reliability, but user feedback from COPD patients could reveal additional needs, such as adjustable speed settings, emergency stop mechanisms, or voice-controlled commands. Integrating IoT capabilities for remote monitoring by caregivers could also enhance the system's practicality in home and clinical settings.

This project aligns with broader trends in assistive robotics, where automation is increasingly used to improve quality of life for individuals with chronic conditions. By reducing the physical burden of oxygen tanks, the system empowers COPD patients to engage more freely in daily activities, potentially improving both physical health and mental well-being. Future research should focus on large-scale trials in real-world environments, cost-effective manufacturing, and compliance with medical device regulations to facilitate commercialization.

5.0 CONCLUSION

In conclusion, this project successfully demonstrates the feasibility of an autonomous portable oxygen tank system designed to enhance mobility and independence for COPD patients. The integration of ultrasonic sensors, microcontroller-based control, and motorized navigation provides a functional solution for patient-following and obstacle avoidance. While the prototype shows promise in controlled settings, further refinements such as improved sensor accuracy, energy efficiency, and user-centric features are necessary for broader application. By addressing the limitations of traditional oxygen delivery systems, this innovation has the potential to significantly improve adherence to oxygen therapy and overall quality of life for patients. Future work should prioritize real world testing, scalability, and collaboration with healthcare professionals to ensure the system meets clinical and patient needs. Ultimately, this

project underscores the transformative role of robotics in healthcare, offering a practical and innovative approach to chronic disease management.

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Deep Learning-Based Mobile App For Emotion Monitoring In Elderly Care

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ABSTRACT

The emotional well-being of older adults, especially those living alone, significantly impacts their health and quality of life. Loneliness, anxiety, and depression are common issues that often lead to physical health deterioration and reduced independence. Addressing these challenges is essential to improving their overall standard of living. Advancements in technology now allow for real-time emotion monitoring through deep learning models such as Convolutional Neural Networks (CNNs), which can detect emotions like happiness, sadness, and stress from facial expressions. These insights, delivered via intuitive mobile applications, enable caregivers to monitor emotional changes and respond promptly to signs of distress. Unlike traditional wearable devices, software-based systems are more accessible, cost-effective, and user-friendly. They support proactive and empathetic caregiving while reducing stress for caregivers. Integrating emotion monitoring into daily caregiving routines has been shown to enhance mental and emotional well-being, reduce feelings of loneliness, and support a holistic approach to elderly care by fostering emotional connections and promoting independence.

Keywords: Elderly care, Emotion detection, Deep learning, Convolutional Neural Networks (CNN), Facial expression recognition, Real-time monitoring, Mental well-being, Non-invasive system, Blynk IoT, Mobile application.

1.0 INTRODUCTION

As the number of elderly individuals living independently continues to rise, there is an increasing need to address their emotional well-being. Many older adults experience feelings of isolation, loneliness, and stress, which can negatively affect both their mental and physical health. In Malaysia, for example, 95.5% of elderly individuals report experiencing loneliness [1], and a significant number also struggle with anxiety and depression. Neglecting emotional health can exacerbate these conditions and lead to a decline in overall well-being, emphasising the need for practical solutions to support the emotional needs of the elderly. Emotional well being, often overlooked in caregiving, plays a vital role in preventing mental health issues and enhancing quality of life. To address this, the system utilises machine learning and deep learning models to analyse real-time facial expressions captured through images or photos.

1.1 Emotional Well-Being in the Elderly

Emotional well-being is a fundamental component of elderly health, significantly contributing to their overall quality of life and physical well-being. Many older adults, particularly those living alone, are at an increased risk of loneliness and depression due to social isolation and reduced social networks. These factors can lead to complications and affect their ability to adopt compensatory movement strategies [2]. The strong connection between emotional and physical health underscores the importance of promoting emotional well-being among older individuals, as it is closely linked to their ability to remain independent and engage in daily activities. Caregivers play a crucial role in recognising signs of emotional distress and providing timely support; however, they often lack the tools to continuously assess emotional states [3]. Emotion detection technologies present innovative solutions for proactive care.

These systems can help caregivers identify emotional patterns in the elderly, enabling them to take immediate action in response to distressing changes and prevent the escalation of symptoms into serious mental health issues [4].

Integrating AI into elderly care offers immense potential for enhancing emotional health monitoring in older adults. Recent research indicates that AI-enabled applications provide caregivers with timely insights into a patient's emotional and physical status [7]. These emotion detection systems are designed to identify concerning trends, such as prolonged sadness or anxiety, allowing caregivers to intervene promptly based on informed judgment [8]. Figure 2 illustrates an elderly individual using a smartphone. Such technologies support proactive care and can significantly improve the quality of life for older individuals by leveraging advanced algorithms to analyse data from multiple sources. Recent advancements in machine learning and deep learning have transformed emotion detection methodologies, significantly improving the accuracy of emotional state monitoring. Deep learning in the form of Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks is widely used to analyse facial expressions and physiological signals for emotion recognition [5].

1.2 Deep Learning in Affective Computing reference

Affective computing is a field that focuses on recognising and responding to human emotions using technology. In the past, emotion recognition systems used manual features and basic machine learning methods, which often lacked accuracy and flexibility. With the introduction of deep learning, affective computing has improved significantly, especially in recognising facial expressions and emotional patterns. Deep learning models, such as Convolutional Neural Networks (CNNs), are commonly used for analysing facial images. These models can automatically learn features like eye movements, mouth shape, and eyebrow positions, which help detect emotions such as happiness, sadness, anger, and surprise.

Datasets like FER-2013 and AffectNet are often used to train these models. Today, smaller and faster deep learning models such as MobileNet and EfficientNet allow emotion recognition apps to run smoothly on mobile phones. Besides facial recognition, deep learning is also used to analyse emotions from voice and text using models like Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks. CNNs are effective in extracting spatial features from images, while LSTMs process temporal sequences, allowing them to capture subtle variations in emotional states over time. Furthermore, integrating wearable devices equipped with sensors that track physiological responses such as heart rate variability and skin conductance enhances the capabilities of emotion detection systems [6].

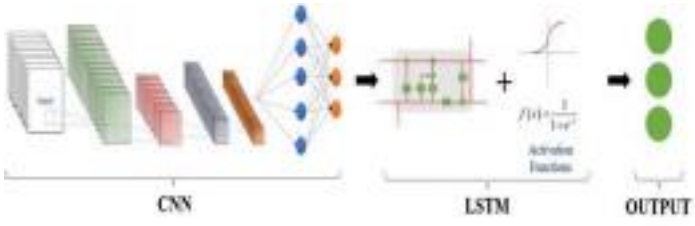

Figure 1; Convolutional Neural Networks (CNNs) and Long-Short-Term Memory (LSTM) networks.[5]

Figure 2: Elderly individual using a smartphone.[8]

1.3 Mobile Health (mHealth) and Emotion-Aware Systems

Mobile health (mHealth) refers to the use of smartphones, wearables, and wireless technology to support health services and medical care delivery. With the rise of smartphones and the growing availability of internet access, mHealth solutions have become more accessible and affordable, particularly for elderly users who require long-term monitoring and care. These applications are often used for tracking physical health indicators such as heart rate, sleep, and physical activity, but in recent years, there has been increasing interest in using mHealth for emotional and mental health monitoring as well. Emotion-aware systems are digital platforms that can detect and interpret a user's emotional state using data such as facial expressions, voice tone, typing behaviour, or physiological signals (e.g. heart rate variability, skin conductance).When integrated into mobile apps, these systems can provide real-time emotional feedback, detect signs of distress or mood disorders, and even alert caregivers or healthcare professionals when needed. For example, emotion recognition based on facial expressions captured through a mobile phone camera has been shown to be effective for mood tracking and depression screening (Khorrami et al., 2017). In elderly care, emotion-aware mHealth systems can support users who may not always be able to express their feelings clearly, such as those with cognitive decline, speech limitations, or social isolation. Affect-aware systems can provide valuable emotional context to caregivers, enabling early intervention when negative emotional patterns are detected. However, many existing systems still face challenges such as low accuracy in real world settings, lack of personalisation, and concerns over user privacy (Saneiro et al., 2019).

2.0 METHODOLOGY

The system was implemented as an Android smartphone application, allowing users to either capture facial images using the phone's camera or select existing images from the phone's gallery. Unlike real-time monitoring, this system analyses emotions from static images, offering periodic emotional data while prioritising ease of use and user privacy. The app was developed using Android Studio, which served as the integrated development environment (IDE) for designing the mobile application. It featured a minimalist user interface that allowed users to either capture a new image or select one from their device's gallery. The emotion detection model was trained using Python in Visual Studio Code, utilising OpenCV for facial feature extraction and NumPy for handling image data.

A Convolutional Neural Network (CNN) was trained on a labelled dataset containing various facial expressions representing emotions such as happy, sad, angry, surprised, drowsy, and neutral. Once trained and validated, the model was converted to TensorFlow Lite format to ensure efficient on-device processing. This allowed the application to detect emotions offline,

preserving user privacy while maintaining real-time performance and accuracy. The face detection module identifies facial landmarks with a focus on mouth curve (for smiling), eye openness (for sleepy), and overall face count in the image. Age group classification (young or adult) was also included to expand demographic surveillance. The image is pre-processed as it is converted to grayscale, resized, and normalised before being passed to the analyser.

Figure 3: Face Emotion Classification. [12]

As shown in Figure 3, the system starts when the user either captures a new photo using the camera or selects one from the gallery. The image is then passed to the FaceAnalyzer module, which identifies faces and analyzes each for emotions (e.g., happy, sad), drowsiness (awake or sleepy), and age group (young or adult). The results are displayed on the app's interface. The user is then presented with an option to save the analysis. As shown in figure 4, if they choose to save, the information is stored for future reference or monitoring.

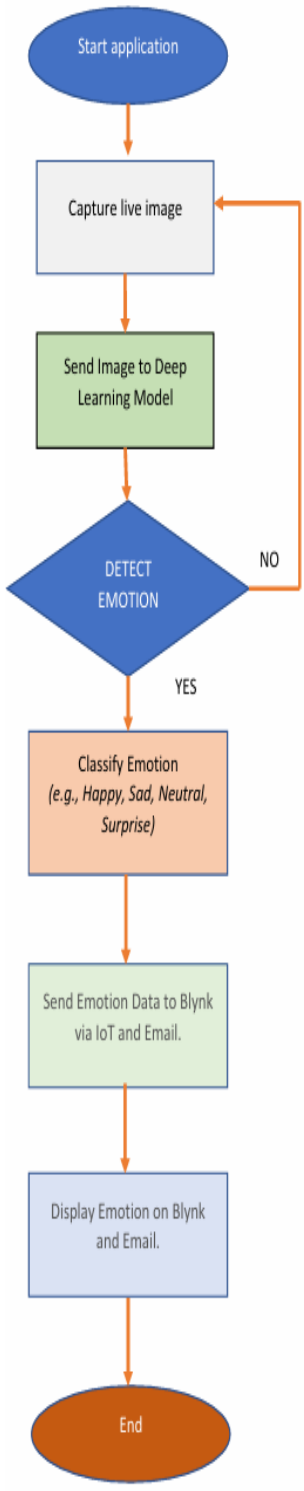

Figure 4: Flowchart for the facial expression system.

2.1 Training the CNN Model

As shown in Figure 5, the emotion classification model was trained using Python in Visual Studio Code, utilising the FER-2013 dataset sourced from Kaggle. This dataset contains 48x48-

pixel grayscale facial images labelled with seven emotional categories: happy, sad, angry, surprise, disgust, fear, and neutral. Before training, the dataset underwent pre-processing and augmentation techniques such as horizontal flipping, random rotation, saturation adjustment, and Gaussian blurring. These steps helped enhance the model's ability to generalise by simulating natural variations in facial expressions and image conditions. The Convolutional Neural Network (CNN) architecture was trained over 107 epochs, achieving a training accuracy of 84%.

Training for fewer than 100 epochs yielded suboptimal results, with accuracy falling below 80%. After fine-tuning, the final model was converted into TensorFlow Lite (TFLite) format to support mobile deployment. This conversion reduced the model size and enabled fast, on device emotion detection within the Android application which is Blynk. The use of TensorFlow Lite ensured that the app could function offline, preserving user privacy while providing real-time emotional insights, especially valuable for elderly users who may have limited access to consistent internet connectivity.

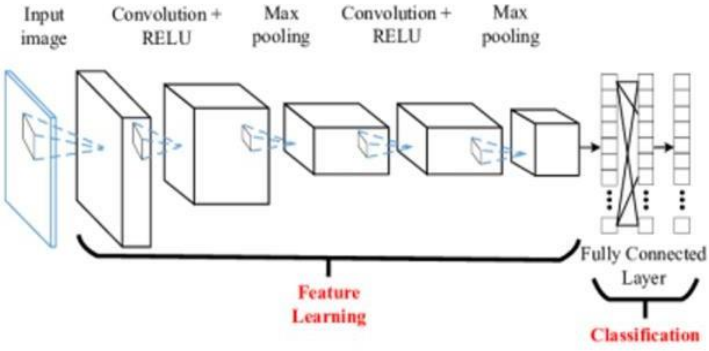

Figure 5: CNN architecture.[13]

2.2 App Development and Integration

In this project, the software application is developed using Python and OpenCV to capture and analyse facial expressions in real-time from a laptop's webcam. The system utilizes a pre trained emotion detection model to detect the user's emotion and classify it into Happy, Sad, Angry, Surprise, Fear, and Neutral. Upon identifying an emotion, the same is immediately published on two platforms: (1) Email, where the label of the emotion and the face image are transferred to a predefined recipient, and (2) the Blynk IoT dashboard, where the identified emotion is remotely visualized through virtual pins. This combination of computer vision and IoT allows the system to perform real-time emotion monitoring without the requirement for a mobile app or hardware-based sensors. The idea is to assist caregivers in monitoring elderly adults who live independently and provide them with prompt care when emotional distress is detected.

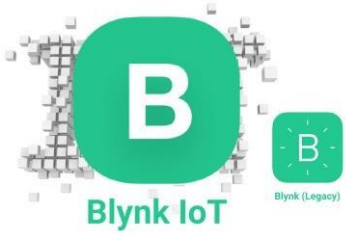

Figure 6: Blynk.[11]

3.0 RESULTS AND DISCUSSION

Dataset	Accuracy (%)	Loss (%)	Error Rate (fraction)	Error Rate (%
Train	95	16	25/40	62.5
Validation	53	31	25/40	62.5
Train	93	29	—	—
Validation	53	40	39/80	48.7
Train	98	53	—	—
Validation	79	79	40/120	33.3

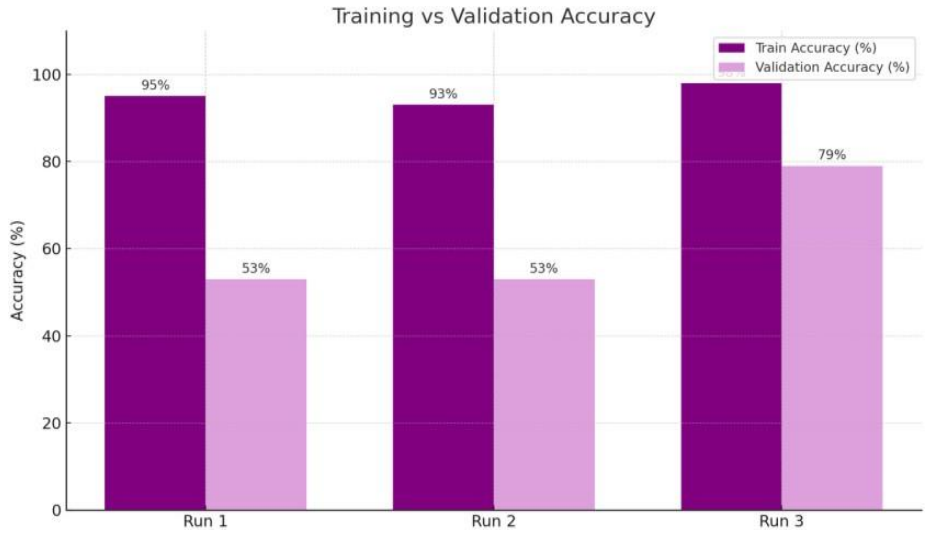

Figure 7, Bar chart comparing Training vs Validation Accuracy across three different runs of the model. It clearly shows the improvements and consistency of training accuracy, while also highlighting the increasing trend in validation accuracy, especially in Run.

As shown in Figure 7, the training and validation accuracy of three runs of the deep learning model used in the mobile app for emotion monitoring in elderly care. It is apparent from the bar chart and table that training accuracy was high (ranging from 93% to 98%), indicating that the model effectively learned features from the dataset. The validation accuracy was lower initially (53%), indicating underfitting or poor generalisation, but rose considerably in the third run to 79%, reflecting better model tuning and greater performance on unseen data. The declining validation error rate over runs attests to enhanced robustness, rendering the app more dependable in accurately detecting emotions in real-world elderly care applications.

4.0 CONCLUSION

This project was successful in developing a photo-based facial emotion recognition application using Android Studio that would assist caregivers in tracking the emotional condition of the elderly. Processing static images instead of live video, the system provides a simple, privacy aware, and low-cost method for the detection of emotional distress indicators, like fake smiles

or low eye openness. The app's offline functionality ensures user data remains secure while still delivering real-time analysis. Overall, the system demonstrates strong potential for integration into broader healthcare monitoring solutions aimed at enhancing the emotional well-being of ageing populations

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Development Kinetic-Powered Wearable Health Monitoring Device for Assessing Well-Being Based on Vital Signs

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ABSTRACT

The project introduces a wearable health monitoring device designed for real-time assessment of well being through non-invasive tracking of vital signs. This device integrates multiple sensors, including those for heart rate, temperature, blood glucose, and galvanic skin response (GSR), offering a comprehensive evaluation of the user's physiological state. Unlike existing wearable devices that often focus on a single health parameter, this solution provides a multifaceted view of well-being. Data from the sensors are transmitted to a mobile application, allowing users to monitor and visualize trends in their health metrics conveniently. The device incorporates motion-based energy harvesting technology to enhance battery life, ensuring uninterrupted data tracking. With this integrated approach, users can proactively manage their health, allowing for early detection of potential health concerns and contributing to overall lifestyle improvement. This innovation has broad implications for preventive healthcare, emphasizing accessible, user-friendly health monitoring outside of clinical environments

Keywords: Wearable health monitoring, Galvanic skin response (GSR), Heart rate monitoring, Blood glucose sensor, Temperature sensor, Mobile health application

1.0 INTRODUCTION

In recent years, the advancement of technology has transformed healthcare, enabling continuous health monitoring beyond traditional clinical settings. Wearable health monitoring devices, integrated with sensors, analytic, and wireless communication, have emerged as powerful tools for assessing well-being by tracking vital signs in real time. These devices provide users with valuable insights into their physiological state, allowing early detection of abnormalities, preventive care, and lifestyle optimization. Vital signs such as heart rate, body temperature, oxygen saturation, respiratory rate, and blood pressure are key indicators of an individual's health status. Monitoring these parameters continuously through wearable devices not only helps in managing chronic conditions but also enhances overall well-being by encouraging proactive health management. The ability to track health data in real-time has shifted the focus from reactive treatment to preventive care, fostering a healthier lifestyle and reducing healthcare costs. Maintaining continuous awareness of personal health and well-being has become increasingly important, especially with the rising prevalence of chronic diseases such as cardiovascular disorders, diabetes, and respiratory conditions. Traditional health monitoring methods, such as periodic medical check-ups, are often insufficient for early detection of health deterioration, as they only provide snapshots of an individual's condition. This lack of real-time monitoring increases the risk of missed warning signs and delays in necessary interventions, potentially leading to adverse health outcomes. Wearable health monitoring devices offer a potential solution by enabling continuous tracking of vital signs, including heart rate, blood pressure, oxygen levels, respiratory rate, and body temperature. However, the adoption of these devices faces several challenges, such as limited functionality of current well-being devices: Existing wearable health monitors often focus on a single parameter [1]. Lack of stress detection in many health monitors: Stress and emotional health are often overlooked by traditional health monitors, even though they are critical factors in overall wellness. GSR can be a valuable tool for measuring stress but is not commonly included in personal health devices [2]. Limited battery life and user comfort. Many wearable health

monitoring devices struggle with limited battery life, especially when continuously tracking multiple health metrics. This limitation often forces users to recharge frequently, disrupting consistent monitoring and reducing the practicality of these devices for long-term use [3]

1.1 Design innovation

The circuit design as shown in Figure 1 process can cover systems from complex electronic systems to individual components in integrated circuits. A systematic approach with intelligently guided computer simulations such as proteus, thinker Chad, AutoCAD, and others. The project that was created in a thinker cad to get a full description of the project. Figure 1 shows the complete design of the project that can be used for the wearable health monitoring device for assessing well-being based on vital signs. For the first phase is the construction of a flow chart. This flowchart diagram represents the design and processing of the illustration. Software system development can be divided into three parts which are schematic circuit, simulation circuit including arduino coding and printed circuit board (pcb) layout.

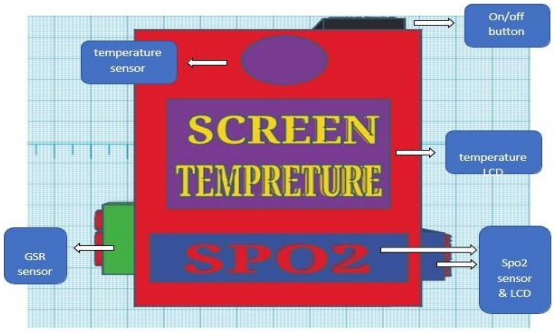


Figure 1: Health Monitoring design

2.0 METHODOLOGY

The methodology for this project is structured to ensure the effective design, development, and evaluation of the wearable health monitoring device. It begins with an extensive review of existing health monitoring technologies and the identification of vital parameters, including heart rate, body temperature, GSR, and blood glucose. The hardware design involves assembling components such as sensors and microcontrollers, while the software framework is developed to process and display real-time data on a mobile application using the Blynk platform. To enhance energy efficiency, piezoelectric-based kinetic energy harvesting is incorporated into the design. The device prototype is tested with respondents to validate functionality, accuracy, and user-friendliness. Finally, performance metrics are compared with existing solutions, and results are documented to ensure reliability and effectiveness.

2.1 Frame work of the project

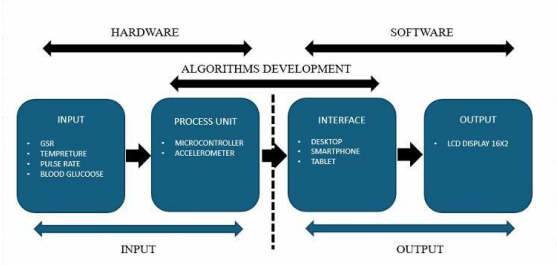


Figure 2: Framework of the project

A framework of the project as shown in Figure 2 is especially focused on the input and output of a system. It cares less about what happens getting from input to output. Figures 2 show the block diagram of wearable health monitoring device for assessing well-being based on vital signs. There are 4 block diagrams consisting of sensors, micro controller Arduino, LCD, and IOT smart phone.

2.2 Flowchart of the project

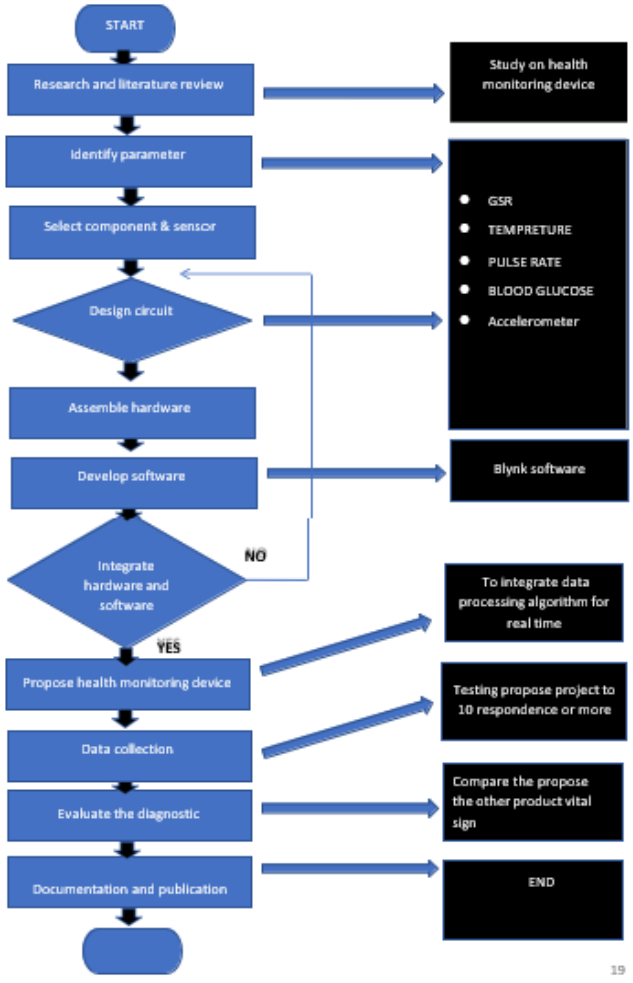


Figure 3: Flow Chart Simulation System of project

A flowchart as shown in Figure 3 can depict a single step of a process. Flow chart figure 3 shows the flow chart of the project implementation flow chart. This flowchart shows the manufacturing process and the steps taken into account throughout the project. This implementation flowchart can be used for 6 months or 1 semester.

3.0 RESULTS AND DISCUSSION

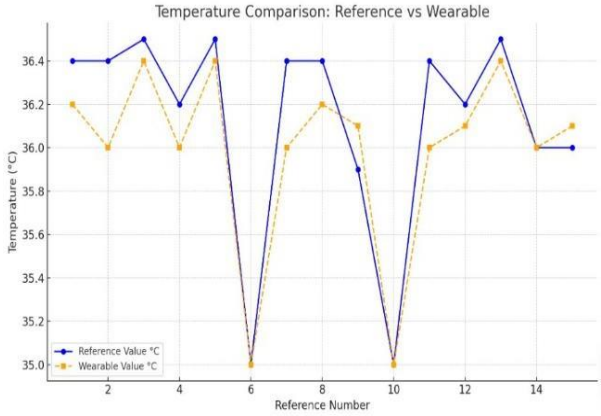
This chapter discusses the findings and results of the analysis conducted for this project. After the development of the Kinetic Powered Wearable Health Monitoring Device for Vital Signs Based Wellness Assessment was completed, the device was tested on patients and the general public. A detailed explanation of the results is provided in this chapter, including how the data was collected and how it was analyzed. The analysis is important to determine whether the health monitoring system is accurately tracking vital signs and whether the health early warning notification function.

3.1 Data & Analysis of Temperature:

Table 3.1: Data of temperature

Rerefence	Actual Value °C	Wearable Value °C	Different
1	36.4	36.2	0.2
2	36.4	36	0.4
3	36.5	36.4	0.1
4	36.2	36	0.2
5	36.5	36.4	0.1
6	35	35	0
7	36.4	36	0.4
8	36.4	36.2	0.2
9	35.9	36.1	-0.2
10	35	35	0
11	36.4	36	0.4
12	36.2	36.1	0.1
13	36.5	36.4	0.1
14	36	36	0
15	36	36.1	-0.1
Average	36.12	35.99333333	0.126666667
% Error			0.003506829

The table 3.1 presents a comparison of body temperature readings between a reference device (Actual Value °C) and a wearable device across 15 measurement instances. Each row shows the actual value, the corresponding wearable value, and the difference between them. Most differences range between 0.0°C and 0.4°C, with only a few small negative deviations (e.g., -0.2°C at reference 9 and -0.1°C at reference 15), indicating that the wearable device tends to slightly underestimate the temperature in some cases. The average actual temperature recorded was 36.12°C, while the wearable device recorded an average of 35.99°C, resulting in an average difference of 0.127°C. The percentage error is minimal at 0.0035 (or 0.35%), suggesting that the wearable device provides highly accurate and consistent temperature readings when compared to the reference.



Graph 3.1: Comparison of temperature

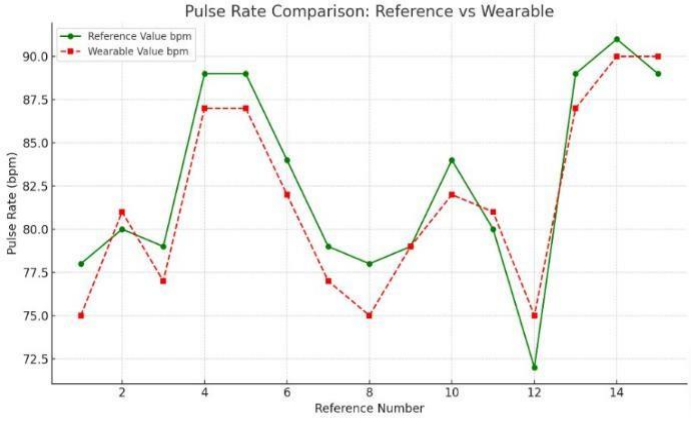
The graph 3.1 illustrates a comparison between temperature readings from a reference device and a wearable device across 15 measurement points. Both data sets follow a similar trend, indicating that the wearable device closely matches the reference values. Although there are slight variations at certain points, the overall consistency suggests that the wearable device provides reliable temperature measurements. Notable dips at reference numbers 6 and 10 appear in both sets, further confirming the wearable's ability to detect temperature fluctuations accurately. This comparison demonstrates the wearable device's potential for dependable temperature monitoring.

3.2 Data & Analysis of Pulse Rate:

Table 3.2: Data of pulse rate

Rerefence	Actual Value (bpm)	Wearable Value (bpm)	Different
1	78	75	3
2	80	81	-1
3	79	77	2
4	89	87	2
5	89	87	2
6	84	82	2
7	79	77	2
8	78	75	3
9	79	79	0
10	84	82	2
11	80	81	-1
12	72	75	-3
13	89	87	2
14	91	90	1
15	89	90	-1
Average	82.666667	81.66666667	1
% Error			0.012096774

The table 3.2 shows a comparison between actual heart rate values and those measured by a wearable device across 15 samples. For each sample, the difference between the actual and wearable values is calculated. The results indicate that the wearable device closely follows the actual heart rate, with an average actual value of 82.67 bpm and an average wearable value of 81.67 bpm. The average difference is just 1 bpm, and the average percentage error is approximately 1.21%. This suggests that the wearable device provides reasonably accurate heart rate readings.



Graph 3.2: Comparison of pulse rate

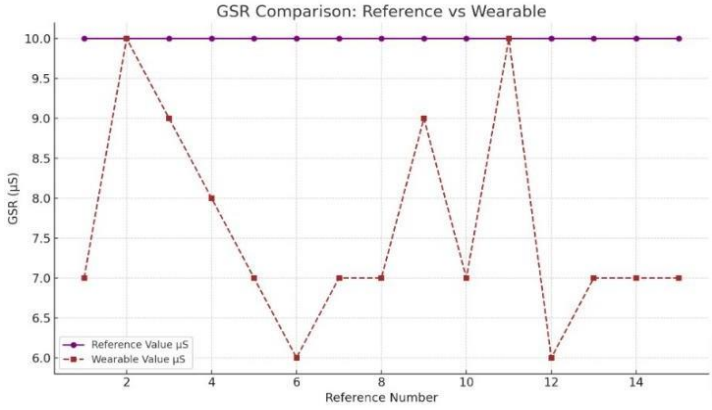
The graph 3.2 illustrates the comparison of pulse rate values recorded by a reference device and a wearable device across 15 reference numbers. Both data sets show a similar overall trend, indicating that the wearable device can effectively follow changes in heart rate. Although slight differences are visible at some points—for instance, around reference numbers 5, 9, and 12 the readings remain relatively close. A sharp drop is observed at reference number 12 in both data sets, suggesting consistent detection of pulse rate changes. Overall, the wearable device demonstrates good agreement with the reference measurements, supporting its potential for reliable heart rate monitoring.

3.3 Data & Analysis of GSR:

Table 3.3: Data of GSR

Rerefence	Reference Value µS	Wearable Value µS	Different
1	10	7	3
2	10	10	0
3	10	9	1
4	10	8	2
5	10	7	3
6	10	6	4
7	10	7	3
8	10	7	3
9	10	9	1
10	10	7	3
11	10	10	0
12	10	6	4
13	10	7	3
14	10	7	3
15	10	7	3
Average	10	7.6	2.4
% Error			0.24

The table 3.3 presents a comparison between reference values and measurements taken by a wearable device for skin conductance, measured in micro siemens (µS), across 15 samples. The reference value remains constant at 10 µS for all samples, while the wearable device readings range from 6 to 10 µS. The difference between the reference and wearable values varies from 0 to 4 µS. On average, the wearable device records a value of 7.6 µS, which is 2.4 µS lower than the reference. The calculated average percentage error is 24%, indicating that the wearable device tends to underestimate the actual skin conductance and shows a relatively higher margin of error compared to the reference.



Graph 3.3: Comparison of GSR

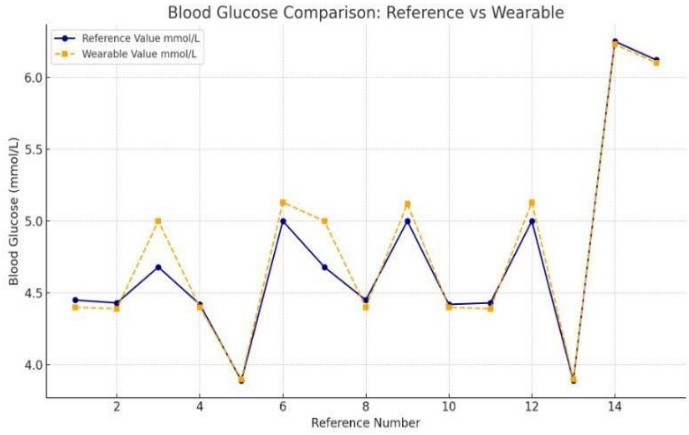
The graph 3.3 illustrates a comparison between the Reference and Wearable Galvanic Skin Response (GSR) values across 15 measurements. The reference values remain consistently at 10 µS, forming a straight horizontal line, while the wearable values fluctuate between 6 µS and 10 µS. This variation indicates that while the wearable device closely matches the reference in some instances (e.g., points 2 and 11), it generally underestimates the GSR readings. The consistent deviation below the reference suggests potential calibration differences or sensitivity limitations in the wearable sensor when compared to the standard reference.

3.4 Data & Analysis of Glucose:

Table 3.4: Data of glucose

Rerefence	Reference Value mmol/L	Wearable Value mmol/L	Different
1	4.45	4.4	0.05
2	4.43	4.39	0.04
3	4.68	5	-0.32
4	4.42	4.4	0.02
5	3.89	3.9	-0.01
6	5	5.13	-0.13
7	4.68	5	-0.32
8	4.45	4.4	0.05
9	5	5.12	-0.12
10	4.42	4.4	0.02
11	4.43	4.39	0.04
12	5	5.13	-0.13
13	3.89	3.9	-0.01
14	6.25	6.23	0.02
15	6.12	6.1	0.02
Average	4.7406667	4.792666667	-0.052
% Error			-0.010968921

The table 3.4 presents a comparison between reference values and wearable device readings for a biochemical measurement in mmol/L across 15 samples. The reference values range from 3.89 to 6.25 mmol/L, while the wearable values range from 3.9 to 5.13 mmol/L. The differences between the two measurements vary slightly, from -0.32 to 0.05 mmol/L. On average, the reference value is 4.74 mmol/L, and the wearable device records a slightly higher average of 4.79 mmol/L. The average difference is -0.052 mmol/L, with an average percentage error of approximately -1.10%. This indicates that the wearable device produces readings that are very close to the reference values, with only minimal deviations.



Graph 3.4: Comparison of glucose

The graph 3.4 compares blood glucose levels (in mmol/L) recorded by a reference device and a wearable device over 15 measurements. The reference values, shown by the dark blue solid line, generally align closely with the wearable values, represented by the orange dashed line. Most data points show minimal variation, typically within ±0.1 to ±0.2 mmol/L, indicating a strong correlation between the two devices. A few measurements, such as points 3, 6, and 12, show slightly higher readings from the wearable, suggesting occasional overestimation. Overall, the wearable device demonstrates a high level of accuracy and consistency in tracking blood glucose trends when compared to the reference standard

4.0 CONCLUSION

This project successfully developed a kinetic-powered wearable health monitoring device capable of assessing user well-being through real-time tracking of vital signs such as heart rate, body temperature, blood glucose, and galvanic skin response (GSR). Unlike many existing devices that monitor only a single parameter, this device offers a holistic view of the user's health, enhancing preventive healthcare measures. The integration of kinetic energy harvesting addresses battery limitations, promoting continuous and reliable usage. Results from initial testing indicate that the device is both accurate and user-friendly, with the potential to positively impact health awareness and early detection of potential health issues. This innovation demonstrates a promising step toward more accessible, energy-efficient, and comprehensive personal health monitoring systems.

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Development Of A Real-Time Emergency Response Coordination Application

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ABSTRACT

Efficient coordination in emergency situations is essential to ensure timely intervention and effective management of critical incidents. However, current systems often suffer from delayed communication, lack of real-time tracking, and poor navigation support, especially in unfamiliar or rural areas. To overcome these issues, a real-time emergency response coordination application is proposed. This application is designed to streamline emergency reporting, enhance communication with relevant services, and provide live status updates and location tracking to users. Developed using Flutter, VS Code, Android Studio and Thunkable, the system features a user-friendly interface and integrates Geographic Information System (GIS) for accurate navigation and route optimization. Core functionalities include direct user-service interaction, real-time notifications, and data analytics to evaluate performance and improve emergency response strategies. The application aims to reduce response times, increase transparency, and improve accessibility for users in both urban and rural settings. With its cost-effective and scalable design, the system is suitable for integration into existing emergency management frameworks. Practical testing will validate its functionality, reliability, and impact on enhancing response efficiency and user outcomes.

Keywords: Real-time emergency response, Coordination application, Emergency management.

1. INTRODUCTION

During major global crises, emergency response involves multiple agencies like police, firefighters, medics, military, and civilian groups working across different jurisdictions. However, poor coordination often leads to duplicated efforts, wasted resources, and confusion, as each team focuses on its own tasks without full awareness of others' actions. High uncertainty, urgent time pressures, limited resources, and the involvement of many authorities make crisis response even more complex, resulting in inefficient outcomes. A better coordinated system is needed to improve collaboration and resource management in emergencies. During emergencies, delays in contacting services [1], lack of real-time updates [2], and navigation challenges [3] worsen crisis outcomes. This project aims to solve these issues by developing a user-friendly app that enables instant emergency communication, provides live response tracking, and improves location accuracy especially in remote areas. The goal is to enhance coordination, reduce response times, and evaluate the app's effectiveness through performance analysis.

2. LITERATURE REVIEW

2.1 Coordinating Emergency Response by Competent Teams

ICTs and social networks help improve emergency response by enabling better communication and coordination. During major disasters like the 2010 Pakistan floods, the 2011 Japan tsunami, and the 2011 Thailand floods, online social networks (OSNs) played a key role—letting people share updates, request help, and report local conditions. These platforms serve three critical functions: detecting emergencies, spreading information, and managing crisis response.

Additionally, the rise of smartphones and sensor technologies has further enhanced disaster support, making internet and mobile tech essential tools in emergencies [4].

2.2 Emergency Response Coordination

Emergency response systems combine technology, communication networks, and organizational structures to manage crises, but they often face coordination challenges between agencies like police, medics, and fire departments especially during large-scale disasters. These gaps delay resource sharing and decision-making, worsening outcomes. Real-time emergency response app addresses this by streamlining communication between agencies and victims through features like GPS tracking, automated alerts, and centralized data sharing. By providing live updates and clear roles during evolving crises, your solution bridges these coordination gaps, helping EOCs (Emergency Operations Centres) and responders act faster and more effectively whether during accidents, natural disasters, or mass casualties [3].

2.3 Real Time Tracking

Disaster management operates across four phases - mitigation, preparedness, response, and recovery. Real-time emergency response application specifically enhances the critical response phase by addressing two key challenges: First, it aggregates vital information from multiple sources including GPS locations from victims' smartphones, responder status updates, and environmental sensors. Second, it curates this data into actionable insights, automatically alerting and coordinating the nearest police, medical, and fire teams through an intuitive interface. By focusing on real-time information sharing and decision support during active emergencies, our solution directly improves response times and coordination effectiveness a crucial advancement over traditional disaster management systems that often struggle with delayed or fragmented communication during crises [5].

2.4Application

Mobile application development is growing rapidly and plays a key role in improving communication and accessibility during emergencies. With the ability to operate on portable devices, mobile apps allow users to report incidents, receive real-time updates, and stay connected with emergency services from any location. Advances in mobile hardware and internet connectivity make it possible to develop efficient, responsive applications that support real-time tracking and communication. For this project, these capabilities are used to build a user-friendly emergency response application that adapts to different environments and provides timely support. As mobile systems evolve, the flexibility of such applications ensures they remain reliable and effective in both urban and rural settings. [6].

3. METHODOLOGY

Real-time emergency response coordination app development follows a structured approach, from system design to testing. The app is built using Flutter, VS Code, Android studio, and Thunkable, focusing on a user-friendly interface. Block diagrams and flowcharts are created to show how the system works from detecting an emergency to notifying response teams. The app allows users to report an emergency, see real-time updates, and help responders track their location using GPS and mapping. This approach ensures seamless communication and faster response during an emergency, while testing will be conducted to verify the app’s performance and effectiveness in real-world situations.

Figure 1: Block diagram of the development of a real-time emergency response coordination application.

The block diagram shown in Figure 1 provides a visual representation of the system architecture and operational flow for the development of an emergency response coordination application. The diagram outlines the key components involved, from emergency detection to communication with response teams, illustrating how information is processed and actions are taken to ensure a timely and effective emergency response.

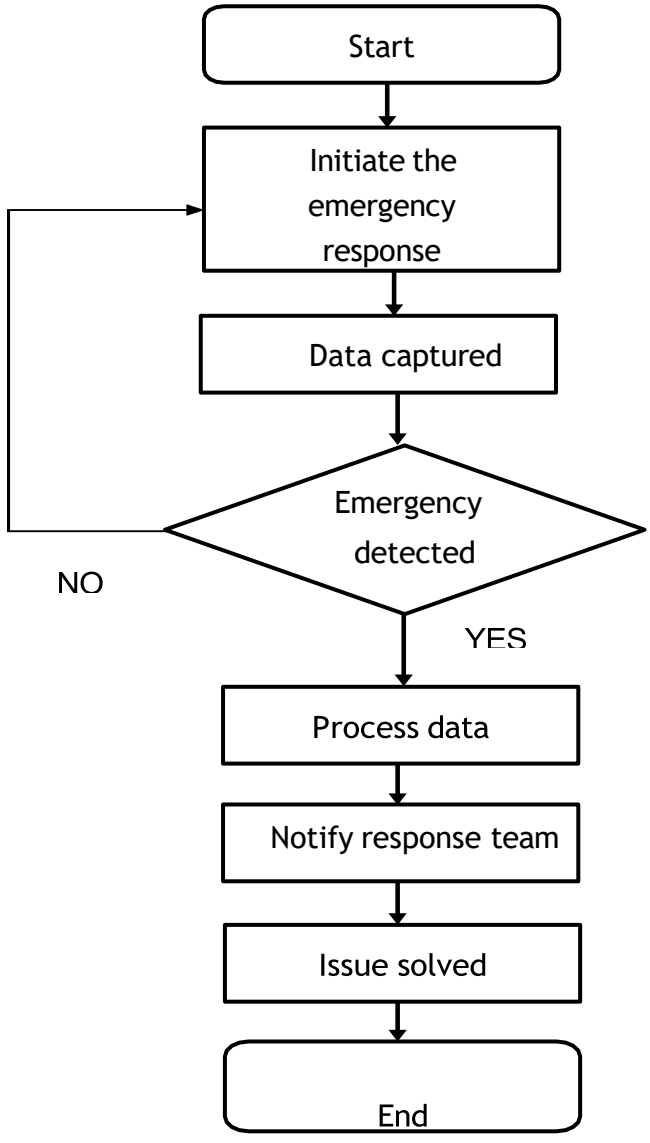

Figure 2: Flowchart of the development of a real-time emergency response

The flowchart as show at figure 2 for the development of the emergency response coordination application outlines the sequential steps of the system's operation, from detecting an emergency to notifying the response team and resolving the issue. It visually guides through the process flow, ensuring a clear understanding of the system's functionality.

3.1 Flutter

Flutter apps are built using 'widgets' - reusable UI components that control how elements look and behave. Unlike React Native which uses native platform widgets, Flutter draws every pixel itself for consistent appearance across iOS and Android. There are two main types: *stateless widgets* (static elements that only update when their data changes) and *stateful widgets* (dynamic elements that can refresh when users interact). While widgets handle most app interfaces, Flutter also allows direct canvas drawing for special cases like games. This flexible system lets developers create fast, customizable cross-platform apps with smooth performance [7].

3.2 VS Code

Visual Studio Code (VS Code) is a popular free code editor from Microsoft that works on Windows, Mac, Linux, and browsers. It's packed with helpful features like error checking, color-coded syntax, smart auto-complete, ready-to-use code snippets, and built-in Git version control. While the official version is proprietary, Microsoft also offers an open-source foundation called 'Code - OSS'. What makes VS Code special is its huge extension library that lets developers add extra tools and customize everything from themes to keyboard shortcuts. According to 2024 developer surveys, about 74% of programmers use VS Code - making it more than twice as popular as its closest competitor [8].

3.3 Android Studio

Android Studio is Google's official tool for building Android apps, available for Windows, Mac and Linux. Built on IntelliJ IDEA, it replaced Eclipse as the main Android IDE in 2015. While free to use (Apache licensed), some included SDK components aren't open source. First announced in 2013, it went through beta testing before its 1.0 release in late 2014. Today it's the only fully supported development environment for native Android apps, offering specialized features for mobile app creation [9].

3.3 Thunkable

Developing applications with Thunkable, there are several academic and practical resources available to guide you in using this no-code platform effectively. Thunkable is designed to allow users to build mobile applications without programming, using drag-and-drop elements to create functional and user-friendly apps for both Android and iOS [10].

4. RESULT AND DISCUSSION

4.1 User Testing

Users engage in a simulation exercise, testing the emergency response coordination app in a controlled virtual training environment. This system provides an interactive platform where responders (police, medics, fire teams) and civilians can practice using the app's features such as real-time GPS tracking, automated alerts, and multi-agency communication to manage simulated emergencies like accidents, fires, or medical crises as show on figure 3.

By replicating high-pressure scenarios, the training system allows users to:

- Evaluate the app's functionality (e.g., accuracy of location sharing, speed of alert dissemination).

- Refine coordination skills between agencies (e.g., role-based task allocation, resource sharing).
- Assess decision-making under time constraints (e.g., prioritizing victims, optimizing routes).

The immersive practice bridges the gap between theory and real-world deployment, ensuring responders and civilians can leverage the app effectively during actual emergencies.

4.2 The Application

This image shows on figure 3, two smartphones displaying a real-time ambulance booking and tracking system developed in this project. On the left screen, the "Ambulance Booking" interface allows users to view nearby ambulances on the map and select one to respond to an emergency. The map shows user and ambulance locations with markers, and both ambulance options (Amin and Syahrul) are listed below with their availability. The right screen shows the view from the ambulance driver's perspective. It displays a message that a request has been received, the ambulance is available, and it shows the request details including the user ID and ambulance ID. This system enables fast and efficient coordination between users and emergency responders using real-time location data.

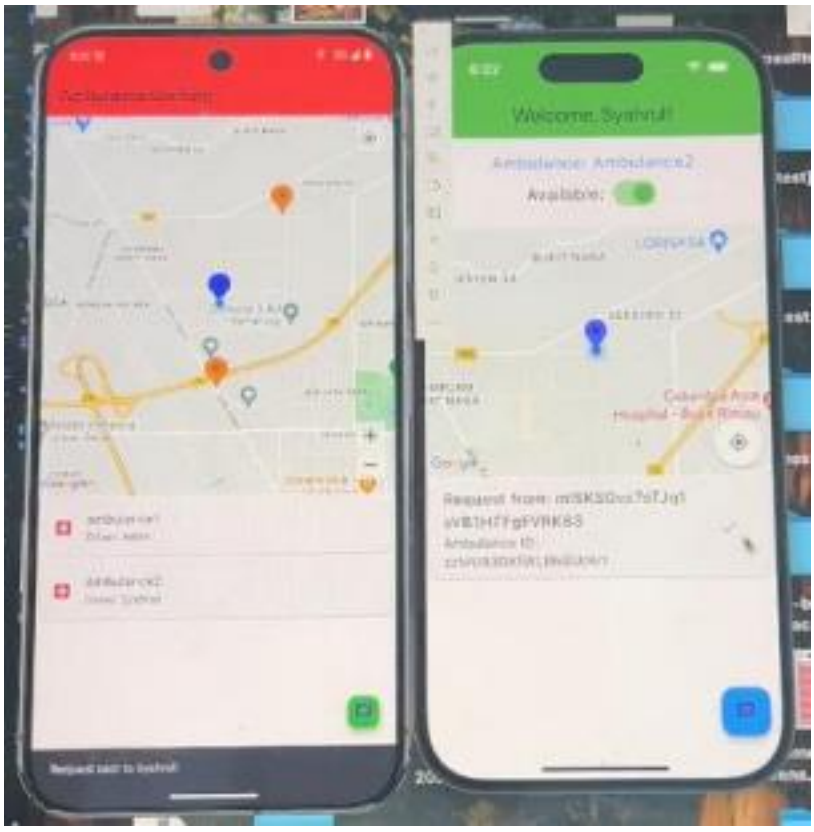

Figure 3: Emergency Application

4.2 Data Collection

In this project, real-world emergency response data is collected from actual crisis scenarios (e.g., accident sites, disaster zones) and integrated into the application's simulation module. Key metrics like response times, location accuracy, and inter-agency communication patterns from real emergencies are used to train and validate the system. By incorporating this authentic data, the app's simulations and real-time coordination features accurately replicate high pressure emergency situations, ensuring responders and users experience scenarios that mirror real-world challenges. This data-driven approach enhances the app's reliability and training

effectiveness for actual emergency deployments. Table 1 summarize the comparison between Manual Emergency Process and Emergency Response App's.

Table 1 Comparison Manual and Application

Feature	Manual Emergency Process	Emergency Response App
Alert Triggering	Phone calls (slow, prone to errors)	Report from app
Location Sharing	Verbal description (inaccurate)	Real-time GPS/GIS tracking
Multi-Agency Coordination	Radio/phone chains (delayed updates)	Live dashboard with role-based alerts
Response Time	15-30 mins (call processing + dispatch)	5-10 mins (automated routing + pre alert)
Resource Allocation	Manual (over/under-deployment common)	AI-driven demand prediction

5. CONCLUSION

The development of a real-time emergency response coordination application is essential to modernizing crisis management and addressing delays in life-saving interventions. This initiative delivers an awareness-driven, technology-driven approach that improves emergency outcomes by enabling immediate communication and accurate coordination between victims, responders, and agencies. The project focuses on integrating GPS tracking, GIS mapping, and automated alerting systems to simulate high-stress emergency scenarios, strengthening response efficiency across police, medical, and fire services. Built with Flutter, VS Code, Android Studio, Thunkable, and real-world emergency data, the app provides a reliable and scalable solution that bridges the gap between emergency reporting and effective multi-agency response. As a result, the system ensures faster assistance, reduces misallocation of resources, and significantly increases survival rates during accidents, disasters, and medical emergencies.

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Development Of A Wearable Device For Hand Tremor Detection And Monitoring In Parkinson's Disease

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ABSTRACT

Parkinson's disease (PD) is a progressive neurological disorder characterized by motor symptoms, with hand tremors being a prevalent and debilitating feature. Traditional tremor monitoring relies on periodic clinical assessments, which fail to capture real-time symptom fluctuations. This paper presents the development of a wearable device integrated with Internet of Things (IoT) technology for continuous hand tremor detection and monitoring. The device employs an MPU-6050 sensor module (accelerometer and gyroscope) to capture tremor amplitude and frequency, processed by an ESP32 microcontroller. Data is transmitted wirelessly via Bluetooth or Wi-Fi to a mobile application powered by Blynk, enabling real-time visualization and cloud-based storage for remote healthcare monitoring. The system is proven to enhance PD management by providing objective, continuous symptom tracking, improving patient care, and facilitating timely treatment adjustments.

Keywords: Parkinson's disease, hand tremors, wearable device, Internet of Things (IoT), real-time monitoring

1.0 INTRODUCTION

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder affecting millions globally, primarily due to the loss of dopamine-producing neurons in the substantia nigra [1]. This leads to motor symptoms such as bradykinesia, rigidity, postural instability, and hand tremors, which affect up to 75% of PD patients [2]. Hand tremors, characterized by involuntary, rhythmic shaking at rest, significantly impair daily activities like eating, writing, and holding objects, reducing patients' quality of life [3].

Traditional tremor monitoring relies on in-clinic evaluations using tools like the Unified Parkinson's Disease Rating Scale (UPDRS), which are subjective and limited to periodic visits [4]. These methods fail to capture daily symptom fluctuations, hindering timely treatment adjustments. Wearable technology, combined with IoT, offers a solution by enabling continuous, objective monitoring of tremor patterns [5].

This paper presents the development of a wearable device for real-time hand tremor detection and monitoring in PD patients. The device uses sensors to capture tremor data, processed by a microcontroller, and transmitted via IoT to a mobile application for visualization and cloud storage. The system aims to improve PD management by providing accessible, real-time data to patients and healthcare providers.

2.0 LITERATURE REVIEW

2.1 Parkinson's Disease and Hand Tremors

PD results from dopamine depletion, causing motor symptoms like tremors, which typically manifest as rest tremors with a "pill-rolling" motion [1]. Approximately 75% of PD patients experience hand tremors, which worsen with disease progression and vary in intensity

throughout the day [2]. Tremors significantly affect daily tasks, making continuous monitoring critical for effective management [3].

2.2 Traditional Tremor Assessment

Clinical assessments, primarily using the UPDRS, evaluate tremor severity on a 0–4 scale based on amplitude and persistence [4]. However, these evaluations are subjective, conducted infrequently, and fail to capture real-time fluctuations. Quantitative methods like electromyography (EMG) and accelerometery provide objective data but require expensive equipment unsuitable for home use [6]. Figure 1 shows the example of scatter plots depicting relationship between total Unified Parkinson's Disease Rating Scale (UPDRS) for 6-minute walk and self-selected walking speed (SSWS) [4].

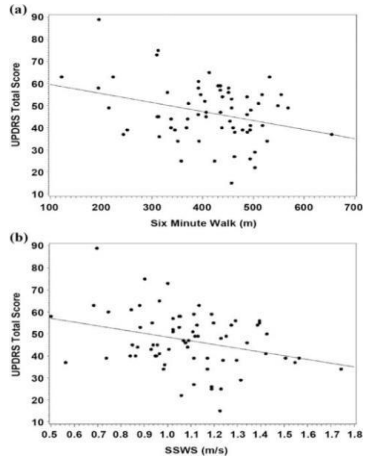

Figure 1: Scatter plots depicting relationship between total of Unified Parkinson's Disease Rating Scale (UPDRS) for (a) 6-minute walk, (b) self-selected walking speed (SSWS) [4].

2.3 Wearable Technology for Tremor Detection

Wearable devices as shown in Figure 2 with accelerometers and gyroscopes have promise in tremor monitoring. Studies have developed wrist-worn devices and sensor-based gloves to measure tremor intensity and frequency with high accuracy [7, 8]. However, challenges like bulkiness, limited battery life, and lack of real-time data transmission persist [9].

Figure 2: Wrist-worn device, with EMG plates and mobile application for the characterization of tremor patterns [7].

2.4 IoT in Healthcare

IoT enables real-time data transmission from wearables to cloud platforms, facilitating remote monitoring [10]. IoT-based systems for PD tremor monitoring have demonstrated improved disease management by providing continuous data to healthcare providers [11]. However, issues like data privacy, power consumption, and device comfort remain [12].

2.5 Sensor Technologies

Accelerometers and gyroscopes are widely used for tremor detection, capturing linear and rotational movements, respectively [13]. The MPU-6050 as shown in Figure 3 is a 6-axis sensor which 3-axis of accelerometer and 3-axis gyroscopes, is compact and energy efficient, ideal for wearables [14]. Signal processing techniques like Fast Fourier Transform (FFT) analyze tremor frequency between 4–6 Hz for PD to distinguish it from other tremors [15].

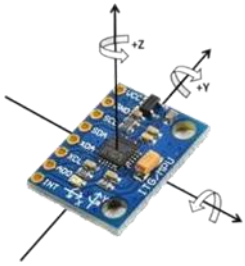

Figure 3: MPU-6050 sensor combines 3-axis Gyroscope and 3-axis Accelerometer [13].

3.0 METHODOLOGY

3.1 Product Development Planning

The development of the wearable device for Parkinson's Disease monitoring progressed through four distinct phases as shown in Figure 4. In Phase I, the need for continuous tremor monitoring was identified through a comprehensive literature review and field studies, highlighting the gaps in existing solutions. Phase II involved designing the wearable device, utilizing cost-effective components such as the ESP32 microcontroller, MPU-6050 sensor, and a Li-Po battery to ensure affordability and functionality. In Phase III, the device is going to test to validate its functionality. Finally, Phase IV focused on analyzing the collected data to assess the device's performance and its potential impact on Parkinson's disease management.

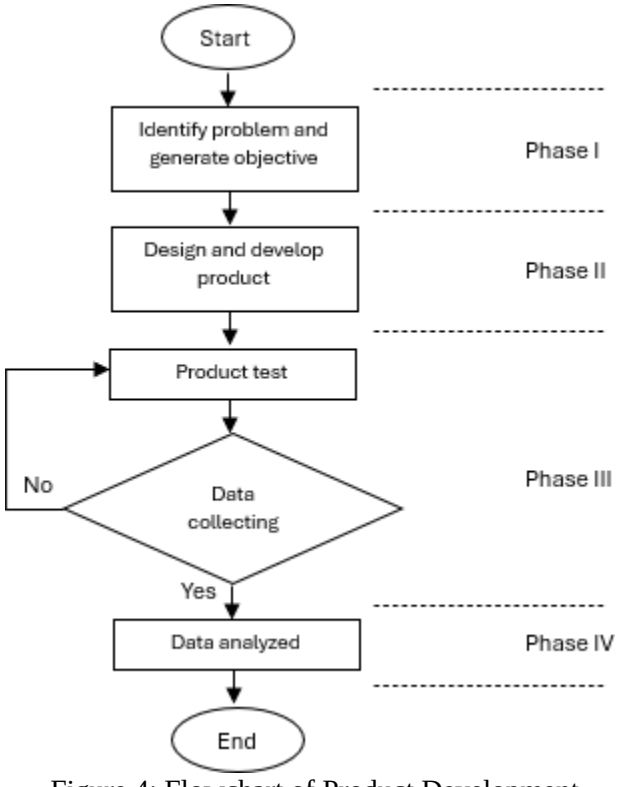

Figure 4: Flowchart of Product Development

3.2 Flowchart of the Project

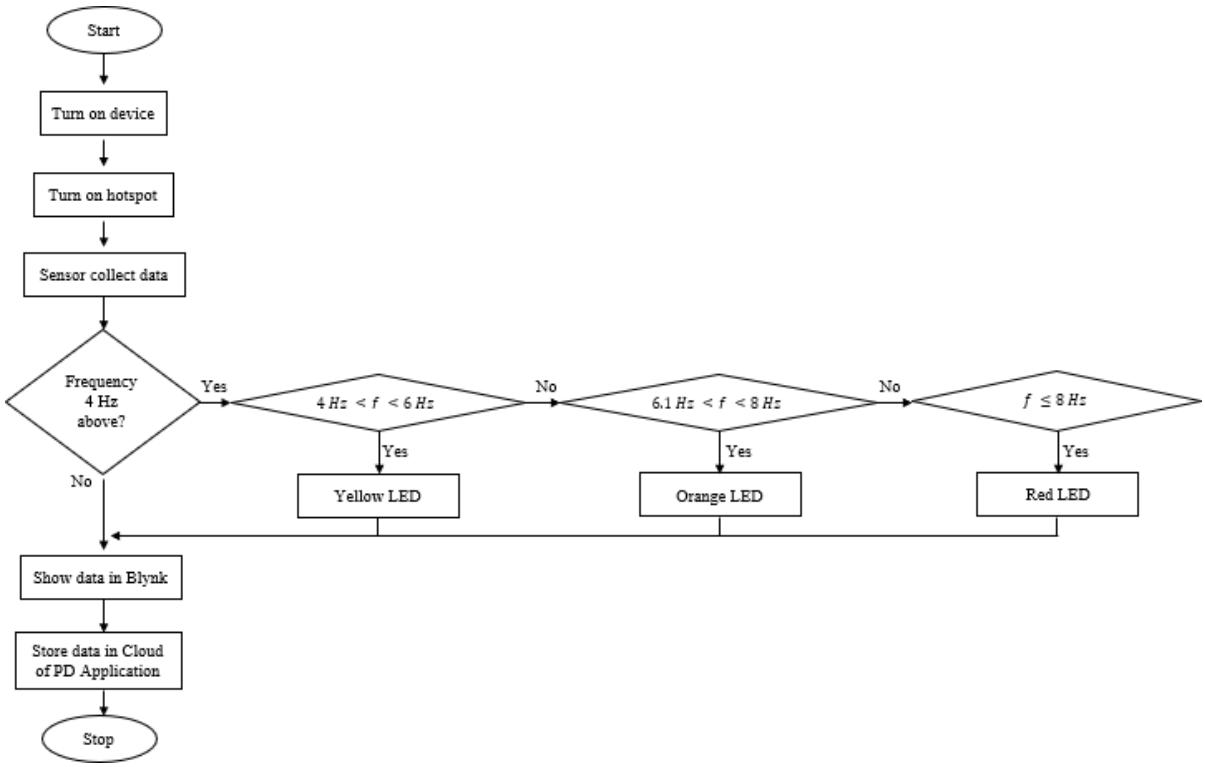

Figure 5: Flowchart of the Project

Figure 5 illustrates the operational flow of the wearable device system developed for detecting and monitoring hand tremors in Parkinson's Disease (PD) patients. The process begins when the user powers on the device, which activates the ESP32 microcontroller and initializes the MPU-6050 sensor along with the status LEDs yellow, orange, and red. Once powered, the device connects to Wi-Fi, either through a predefined network or by enabling its hotspot, allowing communication with the Blynk server and mobile applications. The MPU 6050 sensor continuously collects raw accelerometer and gyroscope data along the X, Y, and Z axes. This data is processed by the ESP32 using a Fast Fourier Transform (FFT) to extract the dominant tremor frequency. Based on the calculated frequency, the system categorizes the tremor severity which a frequency between 4–6 Hz, typically associated with PD resting tremors, triggers the yellow LED between 6.1–8 Hz, indicating moderate or action tremors, activates the orange LED and frequencies above 8 Hz, suggesting severe tremors, cause the red LED to light up. If the frequency is below 4 Hz, no LED is activated. The frequency and amplitude data are then transmitted to the Blynk app for real-time display and are also stored on a cloud platform for long-term tracking, accessible through the MIT App Inventor application. The system continues to monitor and respond in real time until the user powers it off.

3.3 System Design

The wearable device for Parkinson's Disease monitoring integrates several key components to ensure effective functionality and data management. The MPU-6050 sensor captures tremor frequency through its accelerometer and rotational movement via its gyroscope, providing comprehensive motion data. The ESP32 microcontroller processes this sensor data and enables Wi-Fi and Bluetooth transmission for seamless connectivity. A compact, rechargeable Li-Po battery powers the device, ensuring portability and sustained operation. The TP4056 charging module is incorporated to facilitate safe and efficient battery charging. Finally, the Blynk application is utilized to visualize the collected data and store it in the cloud, allowing for real-

time monitoring and data analysis. Figure 6 shows the 3D model of wearable devices that illustrate the prototype for monitoring PD. This 3D model was built by using TinkerCAD software.

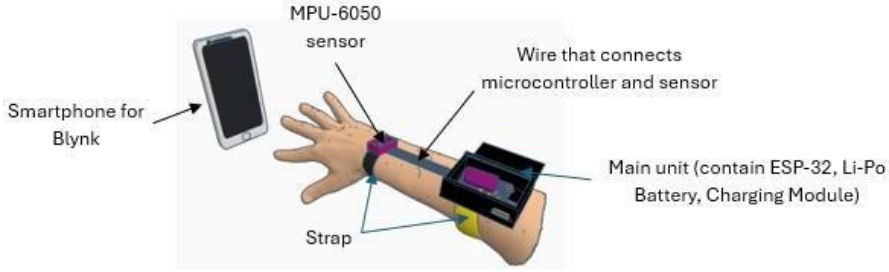

Figure 6: 3D Model of Wearable Devices for Monitoring PD

3.4 Experimental Setup and Analysis Method

The experiment was designed to evaluate the functionality of the wearable device in detecting and monitoring hand tremors, focusing on tremor frequency as key parameters. The experimental setup involved the following steps and configurations.

The wearable device, consisting of an MPU-6050 sensor module, an ESP32 microcontroller, and a Li-Po battery, was assembled into a compact wrist-worn prototype. The device was secured to the subject's wrist using Velcro straps. The ESP32 was programmed to process sensor data and transmit it wirelessly via Bluetooth to the Blynk mobile application for real time monitoring.

Then, ESP32 established a Bluetooth connection with a smartphone running the Blynk app. The Blynk app was configured to display tremor frequency (in Hz), and a "Stream" value representing raw movement intensity. The experiment is conducted on a subject. The subject was instructed to perform natural hand movements, including resting and slight intentional motions, to simulate varying levels of activity. This setup allowed the system to capture both minimal and dynamic movements, providing a baseline for future comparisons with PD patients exhibiting tremors.

The procedure starts when subject wore the device on their dominant wrist. There are 4 conditions for the experiment. First, no hand tremor during walking and secondly no hand tremor while sitting with hand on the table. Third condition is hand tremor that mimicking PD during walking and finally hand tremor that mimicking PD while sitting with hand on table. The MPU-6050 collected acceleration and angular velocity data, processed by the ESP32.

Frequency average was calculated as:

$$f_avg = (fx + fy) / 2$$

Mean Frequency:
f_mean = (the sum of "f_avg" for number of datasets with 4s interval) / number of datasets

Although frequency and amplitude have the Z-axis, it not considered in the calculation because of Z-axis might be mostly static due to gravity 9.8 m/s² when not moving much and including it could distort the average. If the device is worn on the wrist, the Z-axis might not reflect meaningful dynamic movement depending on orientation.

The Blynk app displayed real-time data, including frequency readings and corresponding amplitude values. The data was simultaneously uploaded to a cloud-based storage system via

the Blynk platform, ensuring accessibility for further analysis.

4.0 RESULTS AND DISCUSSION

4.1 Final Product

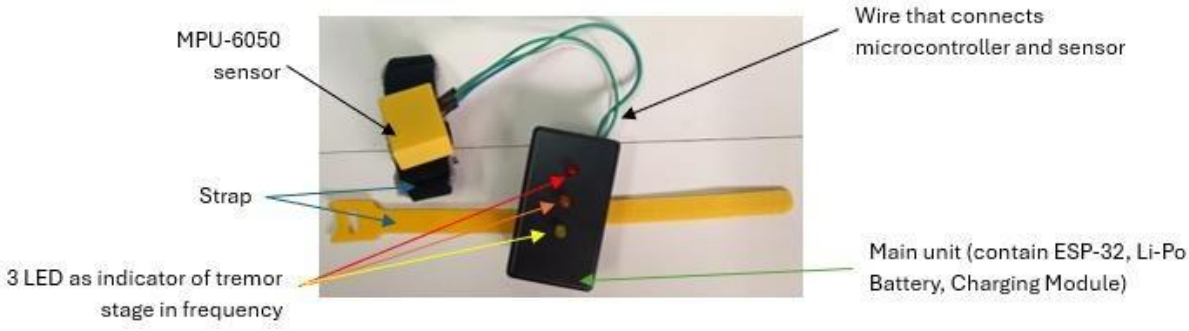

Figure 7: Wearable Devices for monitoring PD

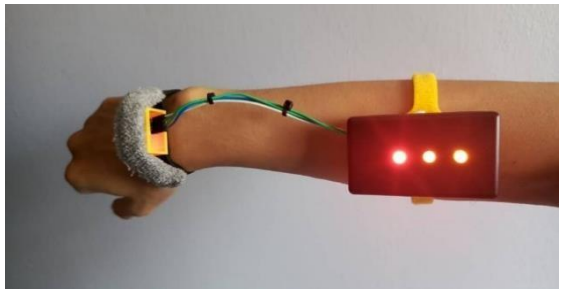

Figure8: Wearable Devices wear on subject's hand

Figure 7 and Figure 8 shows the final product of wearable devices that use to monitor PD. This wearable device detected tremor frequency, a critical parameter for identifying Parkinsonian tremors, which typically range between 4Hz – 6 Hz at rest condition meanwhile, 6 Hz – 8 Hz condition of postural/action tremor [15] where 4Hz - 6Hz classified as mild which triggered yellow LED, 6.1Hz – 8Hz moderate triggered orange LED, and 8 Hz above as severe triggered the red LED.

4.2 Tremor Frequency and Amplitude

The accelerometer data collected under four conditions, first at rest which no tremor during sitting and second is sitting with hand tremor that mimicking PD while putting hand on table. In the no tremor condition, the average frequency was close to 0 Hz, typically ranging between 0 and 0.5 Hz, and the average amplitude was also very low, mostly below 0.1 m/s^2. The amplitudes in the X and Y axes remained minimal, while the Z-axis occasionally showed higher values, up to approximately 8.18 m/s^2, due to the influence of gravity rather than actual movement. This indicates that in the resting state, there was no significant repetitive motion or tremor, and the Z-axis largely reflected static acceleration from the Earth's gravitational pull.

In contrast, for actional tremor during the hand tremor condition that mimic the PD patient movement during walking and no hand tremor during walking, there was a significant increase in both frequency and amplitude. The frequency ranged from approximately 2.2 Hz to 7.1 Hz,

which aligns with typical tremor frequencies observed in Parkinson's disease usually 4–6 Hz. The amplitude values, particularly in the Y-axis, showed strong oscillations, with measurements ranging from -12.8 to +12.8 m/s², indicating dominant motion in that direction. X-axis values also fluctuated but to a lesser extent. The Z-axis showed variable values that not consistently dominant or indicative of tremor-related activity.

The average amplitude was calculated using only the X and Y axes, typically as (|Amp X|+|Amp Y|)/2, excluding the Z-axis. This exclusion is justified because the Z-axis often includes a static component due to gravity, which can distort the interpretation of actual tremor motion. Since tremors usually occur in the horizontal plane X-Y, focusing on these axes provides a more accurate representation of the tremor activity. Including the Z-axis in the average amplitude would introduce unnecessary noise, especially in resting conditions where the Z-axis consistently shows high values unrelated to movement. Therefore, analyzing only the X and Y components results in a more reliable measure for detecting and characterizing hand tremors.

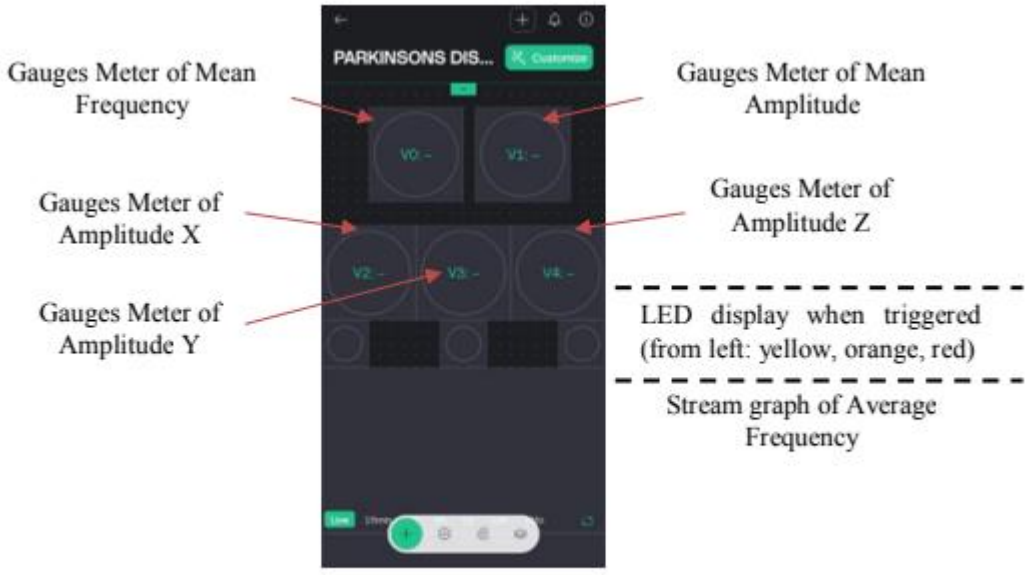

Figure 9: Output display of Frequency, Amplitude and LED in Blynk

Figure 9 shows the user interface of the Blynk mobile application used in the Parkinson's Disease wearable monitoring system. The interface includes several gauge meters and visual indicators that provide real-time feedback on tremor characteristics. Specifically, the gauge meter labelled "Mean Frequency" displays the computed tremor frequency obtained from the MPU-6050 sensor data, which is critical for assessing tremor severity. Three additional gauge meters labelled "Amplitude X," "Amplitude Y," and "Amplitude Z" show the amplitude of hand movements along the respective axes, while another meter labelled "Mean Amplitude" provides a general measure of overall tremor intensity. Below the gauge meters, a row of three LED indicators which are yellow, orange, and red light up according to the detected tremor frequency where yellow indicates mild tremors (4–6 Hz), orange indicates moderate tremors (6.1–8 Hz), and red signals severe tremors (above 8 Hz). Additionally, a stream graph plots the average frequency over time, allowing for visual tracking of tremor fluctuations and trends. This user-friendly interface enables both patients and healthcare providers to easily interpret tremor data in real time for more informed monitoring and decision-making.

5.0 CONCLUSION

This project developed a wearable device for continuous hand tremor detection and monitoring in PD patients, addressing limitations of traditional clinical assessments. The device, equipped with an MPU-6050 sensor, ESP32 microcontroller, and IoT integration via Blynk, provides real-time data on tremor and frequency. The system's affordability and wireless monitoring capabilities make it a practical solution for PD management. Future work includes testing on PD patients to validate tremor detection accuracy and integrating advanced analytics for personalized treatment insights.

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Development of an Adjustable Smart Crutch for Blind Patients

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ABSTRACT
This paper presents the design and development of an adjustable smart crutch for blind patients recovering from lower-limb injuries. Traditional crutches lack adaptability and obstacle detection posing challenges for visually impaired users. This project integrates ultrasonic sensors for real-time obstacle detection to enhanced safety and linear actuators for automated height adjustment. The system is controlled by an Arduino Uno that ensuring responsiveness and user-friendly operation. Testing can improved mobility, reduced physical strain and increased comfort independence for blind users. The proposed solution demonstrates significant potential in assistive technology.

Keywords: Smart crutches, blind patients, ultrasonic sensor and linear actuator.

1.0 INTRODUCTION

Mobility aids such as crutches are essential for individuals with lower-limb disabilities including blind patients recovering from accidents. However, conventional crutches have fixed heights and no obstacle detection making navigation difficult for visually impaired users. In Malaysia, over 45,000 registered blind individuals face mobility challenges highlighting the need for adaptive solutions(Media et al., 2024). This project introduces smart crutch with automated height adjustment (115-144 cm) via linear actuators and ultrasonic sensors to detect obstacles and feedback for real-time alerts. The system aims to enhance safety, comfort and independence for blind users while reducing caregiver dependency.

Crutch are commonly used to support a lower extremity after an injury or surgery that affects balance or weight bearing. Some common injuries that may require crutches included bone fractures such as bone fractures in the leg, ankle, foot, or knee(Thakur et al., 2022). Ligament or tendon injuries such as an Achilles tendon rupture or tendinitis(*Achilles tendon rupture - Diagnosis and treatment - Mayo Clinic*, n.d.). Sports injuries such as sprains, ACL tears or torn meniscus and lastly in surgery lower body such as arthroscopic surgery (*ACL Vs MCL Vs Meniscus Tear | Dr. Pamela Mehta, San Jose*, n.d.).

Crutch are a type of walking aid that serve to increase the size of an individual's base of support. They transfer weight from the legs to the upper body and are often used by people who cannot use their legs to support their weight (from short-term injuries to lifelong disabilities). There are several types of crutches which is axillary (underarm) crutches, forearm crutches and gutter crutches. Underarm crutches the most common type of crutch with a padded top that fits under the armpit, a straight frame and a handgrip. The hand grip distance and total length of the crutch are adjustable. Next, forearm crutches also known as elbow or Lofstrand crutches. These crutch have a supportive cuff that fits around the upper arm and a handgrip. Most of the weight is supported by the hands and they are often used later in the healing process. Gutter crutches also known as adjustable arthritic crutches or forearm support crutches. These crutches have a padded forearm support, a strap and an adjustable handgrip. They are used by patients who are partial weight bearing and are particularly useful for clients with rheumatoid conditions (*Crutches - Physiopedia*, n.d.). When choosing crutches, it is important to consider the user's

body weight and the material of crutches. Aluminium crutches are lightweight and durable while wooden crutches are less expensive but heavier and less durable. Carbon fibre crutches are the lightest but also the most expensive materials.

Numerous medical conditions affect the foot and ankle including diabetic foot ulcers, Charcot neuroarthropathy, Achilles tendon ruptures, foot and ankle fractures and sprains, and surgical procedures such as ankle replacement or fusion. These conditions often require the patients to unload the affected leg for prolonged durations. For example, previous studies have reported periods of approximately 4–8 weeks for ankle fractures, up to 24 weeks for Charcot osteoarthropathy and up to 38 weeks for diabetic ulcers (Elraiyah et al., 2016). Consequently, ambulatory assistive devices are commonly prescribed to facilitate ambulation while avoiding undesired weight-bearing of the affected leg (Bus et al., 2020).

2.0 METHODOLOGY

This project developed an adjustable smart crutches for blind patients reduce pressure while sit and up from chair. In order to facilitate and achieve objective project, the methodology used are hardware the important part is axillary crutches, linear actuator motor for height adjustment and ultrasonic sensor to detect obstacle meanwhile for software using apps Arduino and proteus to sketch the schematic diagram. This chapter also consist of flow chart and process of project.

2.1 Block Diagram

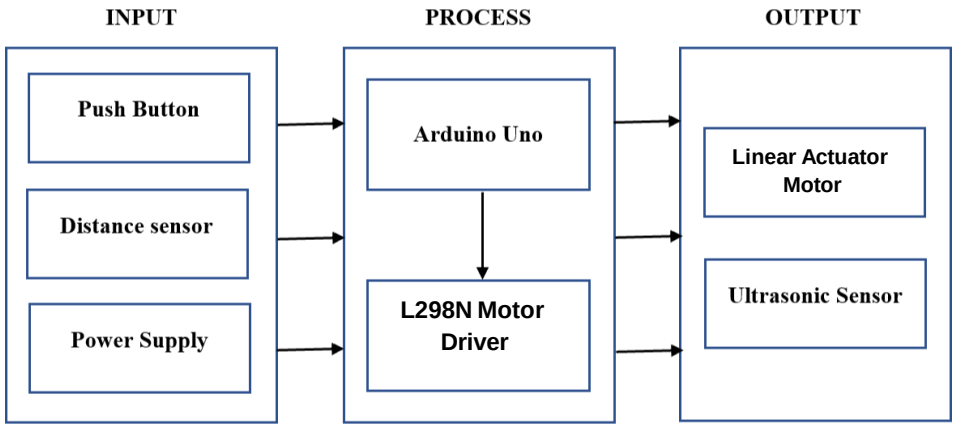


Figure 2.1: Block Diagram of the project

Based on Figure 2.1, block diagram represents an adjustable smart crutch for blind patient controlled by an Arduino Uno microcontroller. The input is when push button turn on to adjust the height then the distance sensor also will turn on. It describes the features of the crutches beginning with the obstacle detection system, including the sensor array, followed by the control system based on Arduino, then the mechanisms for mechanical adjustments to the crutches, all the way to the output systems, including haptic and auditory feedback systems. This setup enables the crutches to adjustable up and down and can avoid obstacle by using ultrasonic sensor.

2.2 Schematics Diagram

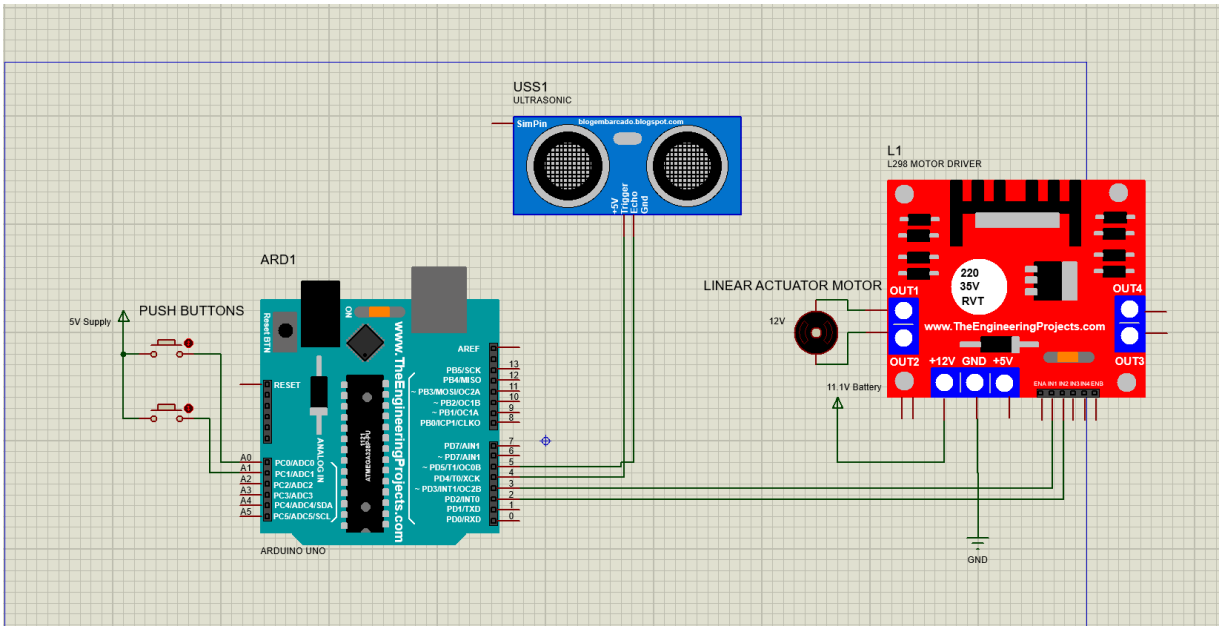


Figure 2.2: The schematics diagram of the project

The schematic diagram shows a circuit arrangement for development of an Adjustable Smart Crutch for blind patients as shown in Figure 2 that include essential elements for detection and automatic modification procedures. The Arduino Uno operates as the main microcontroller within the system under examination labelled as ("ARD1"). The ultrasonic sensor labelled as (USS1 ultrasonic) sends data to the system which enables detection of objects in the user's moving direction. Signals from the Arduino are sent to the L298N motor driver namely "L1 L298 MOTOR DRIVER" that controls the operation of the 12V linear actuator motor. The motor automatically controls modified crutch to extend or retract it according to user navigation needs. The push buttons allow users to control the crutch by themselves whenever needed.

The system achieves portability and operation consistency due to a LiPo battery serving as its power supply. The motor driver functions to control the power flow sent to the linear actuator which permits accurate movements of the system. The real-time changes in the environment are tracked through continuous data observation by the Arduino. The device's output pin components (OUT1-OUT2) create expansion possibilities to introduce vibration, audio alerts and wireless connectivity capabilities.

2.3 Flowchart

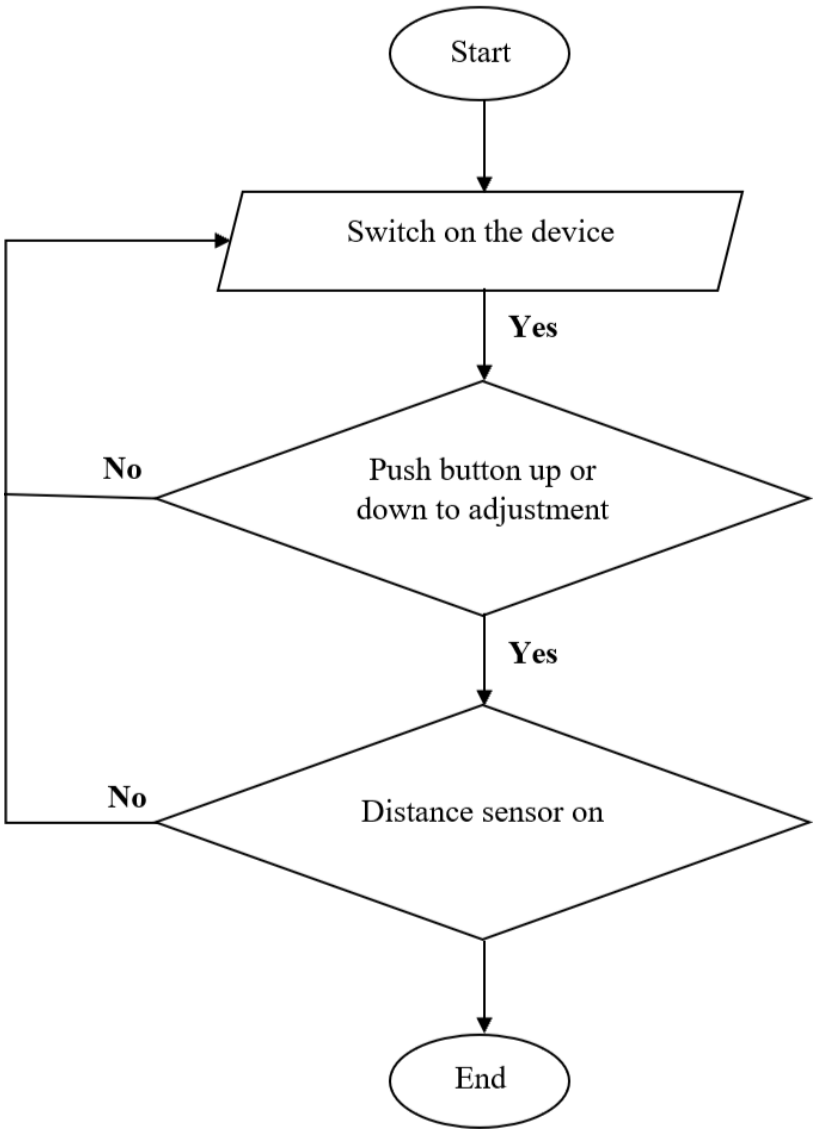
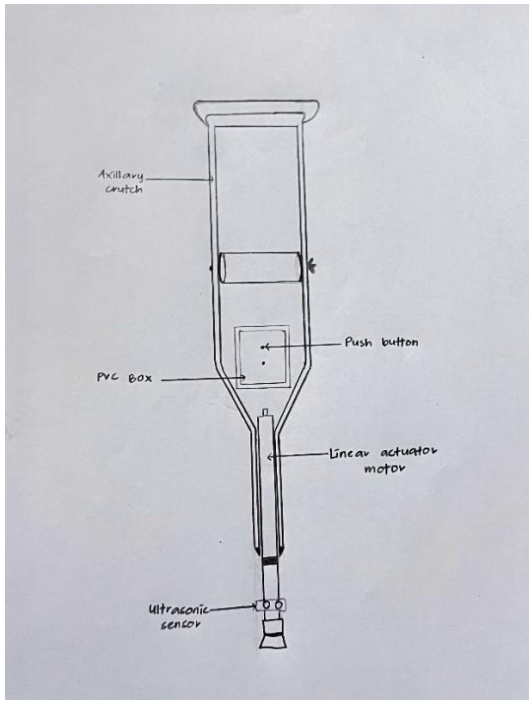


Figure 2.3: The flowchart of the project

Based on Figure 2.3, the process begins when the user switches on the device. Once powered on, the system checks whether the push button for height adjustment is pressed. If the button is not pressed, the system remains idle until input is detected. When the push button is pressed, the crutch proceeds to perform the height adjustment function whether up or down. Following this, the system checks if the distance ultrasonic sensor is activated to detect nearby obstacles. If the sensor is on, the process completes and the system continues to monitor or maintain its state. If not, the system loops back to await proper activation or input.

2.4 Project Design

Figure 2.4: Design of the project



The design of this project as shown in Figure 3.4, centre on creating adjustable smart crutch tailored to meet the specific needs of blind patients who require crutch following accident related lower body injuries. The crutch can adjustable height allowing users to easily change the crutch height to suit different scenarios and individual requirements. This adjustable feature is controlled via a linear actuator or stepper motor system, programmed using an Arduino microcontroller, enabling seamless up-and-down motion at the push of a button.

To enhance navigation and safety, the smart crutches are equipped with ultrasonic sensors to detect nearby obstacles. The sensors send real-time data to the Arduino which then triggers haptic feedback or auditory alerts to inform the user of obstacles. The system's power is supplied by a lightweight, rechargeable battery pack which provides sufficient energy for both the motors and sensors while maintaining portability. With these components integrated into a sturdy, lightweight frame the adjustable smart crutches aim to offer blind users a reliable, supportive and user-friendly mobility aid that enhances both independence and safety.

2.5 3D-Design

Figures 3.5 and 3.6 illustrate the 3D design of the adjustable smart crutch which were created using **SketchUp software**. This software was chosen for its user-friendly interface and precision in modelling engineering components.

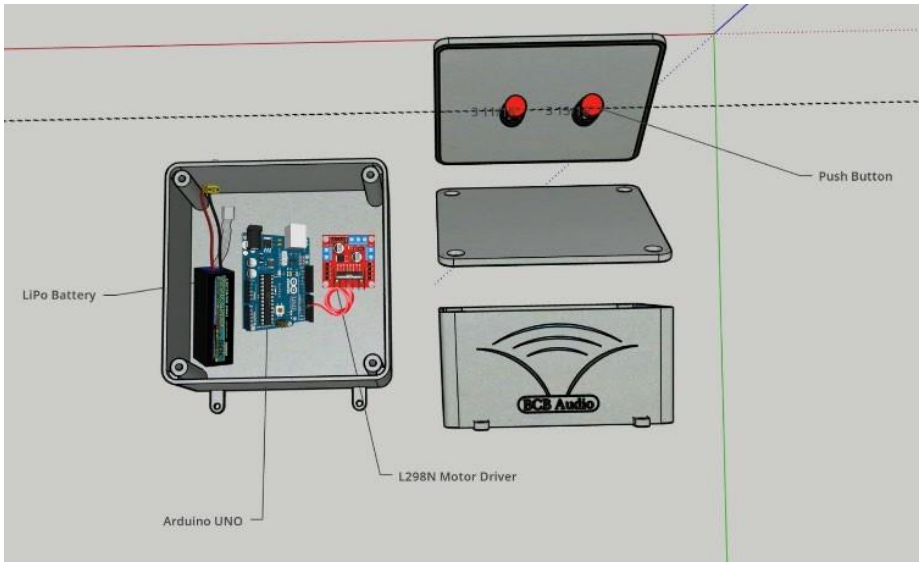


Figure 2.5: 3D-Design for Internal view

Figure 3.5 shows the **internal component layout** including the **Arduino UNO, L298N motor driver, LiPo battery** and **push buttons** all neatly arranged within a protective casing. This design ensures that the electronic parts are securely housed while allowing easy access for wiring and maintenance.

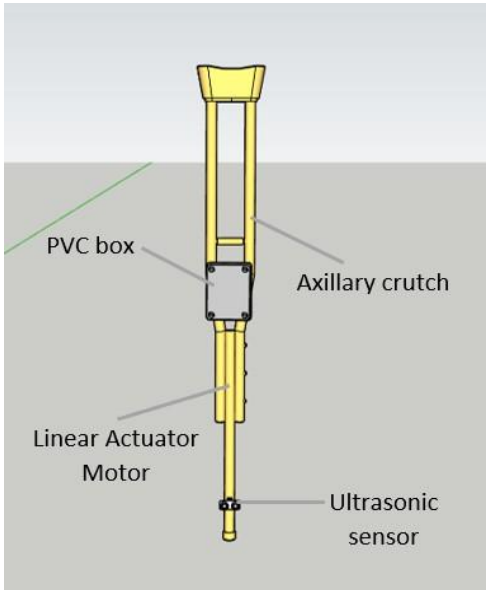


Figure 2.6: 3D-Design for External view

Figure 3.6 displays the **external view of the smart crutch** highlighting how the internal module is seamlessly integrated into the crutch frame. The SketchUp model helps visualize the real-world assembly and spatial arrangement of each component ensuring a practical and ergonomic final product.

2.6 Software

Software plays a crucial role in the development of an adjustable smart crutch for blind patients. In this project, two main software tools were utilized which is **Arduino IDE** and **SketchUp**. This software helped make the job easier by creating the system with ease. Together, these software tools contributed to both the functional and structural success of the smart crutch system.

2.6.1 Arduino IDE

Figure 2.7: Arduino IDE Software

In this project, the adjustable crutch equipped with a smart feature controlled by a microcontroller programmed using Arduino IDE software. Since Arduino IDE platform is open source it is easy to program and incorporate additional features such as haptic feedback required for the particular device. Obstacle detection or simply personalization of the support and flexibility of the crutches could have been programmed through unique commands on the Arduino. This software enables such a device to operate perfectly and to reply fast so that a visually impaired person can do certain things in a short time without being at risk of an accident when on the move.

2.6.2 SketchUp

Figure 2.8: SketchUp Software

In this project, SketchUp software was used to create a detailed 3D model of the adjustable smart crutches. The software allowed for accurate visualization of both the internal components such as the Arduino UNO, LiPo battery and motor driver. The external design of the crutch structure ensuring a compact, functional and ergonomic layout before physical assembly.

2.7 Hardware

The hardware of this project consists of both mechanical and electronic components integrated into a single assistive mobility system. The primary structure is a pair of axillary crutches modified to support embedded electronics for smart functionality. Central to the system is the Arduino UNO microcontroller which processes input and output signals.

Table 2.1: Component of the project

Component	Function
Axillary crutches	Primary support structure for the user, designed to be adjustable in height to accommodate different patient needs.
Arduino Uno	Primary controller which executes sensor data while managing motor operations and managing input/output signals such as button signals and ultrasonic sensor readouts.
Linear Actuator Motor	A linear actuator is ideal for smooth and controlled height adjustments allowing the crutch's length to extend or retract as needed.
L298N Motor Driver	The controller functions to manipulate speed and direction outputs of the linear actuator motor that performs automatic crutch adjustments.
Push Button	The system includes manual control features which users can activate/deactivate to extend the crutch for obstacle avoidance or adjust the height setting.
Ultrasonic Sensor	The sensor system detects obstacles in front of the user which leads to alerts and automatic crutch adjustments through Arduino signals.
LiPo Battery	Provides portable power to the Arduino, motor, and other electronic components.
LiPo Charger	The LiPo battery receives charging power to active system functions.

3.0 RESULTS AND DISCUSSION

3.1 Development of an Adjustable Smart Crutches for Blind Patients

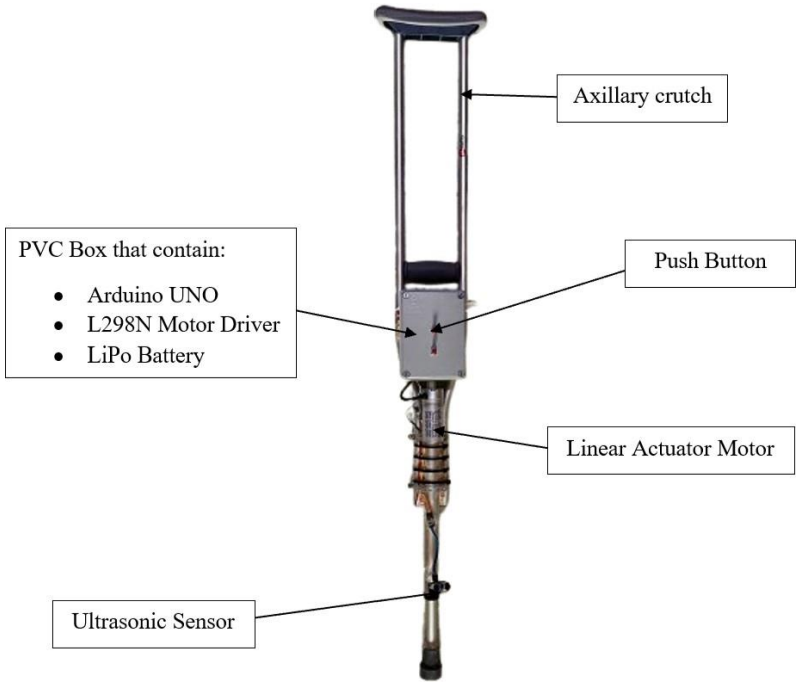


Figure 3.1: Final Prototype of Automatic Crutch

Based on Figure 3.1, the final prototype of development of an adjustable smart crutch for blind patients which include a ready Arduino UNO, LiPo battery, push buttons and motor driver housed in a sturdy casing. The crutch has a linear actuator that stretches for handling height adjustment and an ultrasonic sensor that senses obstacles creating a useful and practical assistive device for practical applications.

3.2 Detection between ultrasonic sensor and object

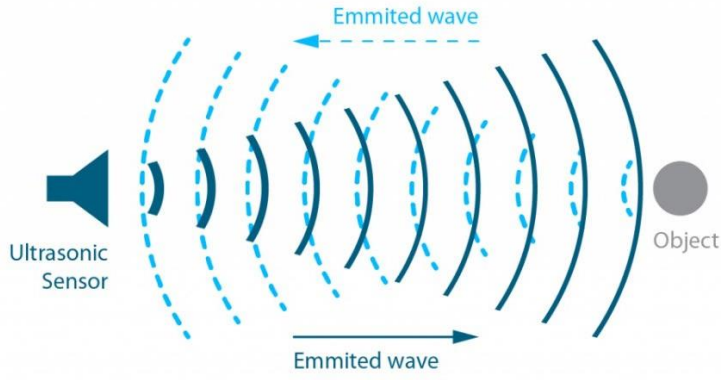


Figure 3.2: Detection obstacle

The sensor emits high-frequency sound waves that travel through the air and bounce back when it encountered an object. The reflected waves return to the sensor which measures the time taken for the echo to return. Using this time and the speed of sound, the sensor accurately determines the distance to the object. It can detect objects precisely without relying on light or making physical contact. Ultrasonic sensors are essential for identifying nearby objects and providing alerts when something is close.

Table 3.1: Distance detection using ultrasonic sensor

Distance between ultrasonic / User	1cm	10cm	20cm
1	/	/	/
2	/	/	/
3	/	/	
4	/	/	/
5	/	/	/
6	/	/	
7	/	/	/
8	/	/	

Based on Table 4.1 at a distance of 1 cm, the ultrasonic sensor worked well for all of the users. This result shows that the sensor is highly sensitive and capable of recognizing obstacles at very close range. Such performance is essential for ensuring immediate detection when the user is near hazards or physical obstructions. However, while detection at 1 cm is stable it may not offer sufficient reaction time for blind users to respond safely. Therefore, this distance is effective for emergency alerts but not ideal for early warning purposes.

Besides that, all users found the 10 cm distance tested worked well in producing accurate results. Thus, 10 cm marks the place where the smart crutch detects best and most accurately. It gives blind users enough notice and time to respond to the signals by stopping, changing direction or planning having the navigation plan. Such reliable detection by the sensor allows for constant buzzing or vibration feedback.

At 20 cm away from the sensor, the accuracy and performance decreased and various users regularly missed the detection. Because of this, 20 cm is found to be too much for the reliability of what the sensor can measure in that setup. Even though most ultrasonic sensors have a range of 20 cm or more surface angle the type of material and reflections can cause inaccuracy. 20 cm is not the right choice for an alert trigger because it might slow down or endanger the user when using the system.

3.3 Adjustment Height using Linear Actuator Motor

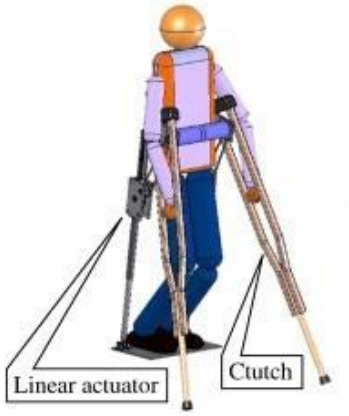


Figure 3.3: Adjustment Height

A linear actuator motor in this project gives the crutch ability to adjust users in many different heights. If the push button is pressed, Arduino will send a signal to the linear actuator motor so it either pulls or pushes the length of the crutch to the required setting. The creation of a crutch design with adjustable height 115 cm–144 cm. The minimum height of crutch 149.4 cm and the maximum height is 187 cm. The height of crutch also adjustable for blind users and easier to detect any obstacle with use of ultrasonic sensor.

The maximum load for linear actuator motor is 1500N which is suitable for user with 152 kg in weight. Since the stroke is 300 mm, the user's leg can be adjusted vertically from a height of 149.4 cm to 187 cm. The process takes 70 mm/s to complete which is quick and smooth making it simple for users to switch positions at any time. Using a duty cycle of 20% also ensures that the device will not get too hot from repeated use, as it is vital for assistive aids that are used frequently. Because of these specifications, the crutch improves posture, reduces soreness during moving and supports ergonomic positioning allowing people with vision or mobility challenges to use it comfortably every day.

Table 3.2: Adjustment ideal crutch

Actual Height (cm)	Crutch Length (cm)	Self-Reported Height (cm)	Crutch Length (cm)
152.4	115	152.4	116.4
162.2	121.8	162.2	123.1
157.1	118.2	157.1	119.6
160.3	120.5	160.3	121.8
153.6	115.6	153.6	117.2
165.9	124.5	165.9	125.6
161.2	121.1	161.2	122.4
169.7	127.2	169.7	128.2

Table 3.2 present the ideal adjustment of smart crutch. Actual height (cm) column represents the actual physical height of each user ranging from 152.4 cm to 169.7 cm. These values are important because they determine the ideal crutch height for each individual. The diversity in user heights allowed the system to be tested across a realistic range of body sizes ensuring that the crutch's adjustability could accommodate users of different statures, particularly those between the minimum range of 149.4 cm and maximum of 187 cm in the project scope because users varied in height, the system was assessed using a realistic height range to ensure it could accommodate individuals between 149.4 cm to 187 cm as specified in the project scope.

The system powered by a linear actuator was able to match these values effectively through automated adjustment showing that the crutches are capable of achieving precise height configurations for optimal user comfort and support.

Table 3.3: Adjustment ideal crutch

User	Actual Height (cm)	Crutch Height Setting (cm)	Time to adjust (s)	Fit Accuracy (%)	User Comfort Score (1-10)
1	152.4	115	5	82.61	8
2	162.2	121.8	5.3	89.16	8
3	157.1	118.2	5.2	85.79	8
4	160.3	120.5	5.3	87.97	8
5	153.6	115.6	5	83.22	8
6	165.9	124.5	5.5	91.57	9
7	161.2	121.1	5.3	88.52	8
8	169.7	127.2	5.6	93.87	9

The time to adjust (s) column shows the amount of time taken for the crutches to reach the desired height after the user pressed the adjustment button. The recorded adjustment times ranged from 5.0 to 5.6 seconds, demonstrating that the linear actuator performs reliably and efficiently. This quick adjustment is crucial for real-time usability especially for blind users who need immediate responsive changes without manual effort or visual confirmation. The slight variation in time is likely due to the different distances the actuator had to travel for each user's ideal height demonstrating that they achieve this for better comfort and support.

Fit accuracy (%) indicates how well the adjusted crutch height aligns with the ideal ergonomic height calculated for each user. The percentages ranged from 84.62% to 93.87%, indicating that the smart crutches were able to provide highly accurate height alignment. This high accuracy is essential to reduce strain on the shoulders and arms ensure proper posture and improve overall user comfort and safety during movement. The results validate the effectiveness of the system's automated adjustment mechanism in meeting user-specific physical requirements.

The user comfort score was measured on a scale of 1 to 10 with all participants scoring the crutches between 8 and 9. These scores reflect a high level of satisfaction with the functionality,

fit and usability of the smart crutches. The consistently high ratings suggest that users found the system not only effective in terms of physical support but also intuitive and easy to operate. The comfort level is especially significant for blind users as it confirms that the integration of technology did not complicate the usage experience but rather enhanced it.

4.0 CONCLUSION

The adjustable smart crutches system demonstrates significant improvements over traditional mobility aids in terms of comfort, safety, and usability. By automatic height adjustment can reduce the pressure while sit and up from chair and detect obstacle surrounding while walking. The device promotes better rehabilitation outcomes especially for blind patients and reduces risk of secondary injuries. Future enhancements may include AI-based gait analysis and solar powered energy modules for outdoor use. This project proves that even simple mobility aids can benefit greatly from modern sensor and communication technology.

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Development Of An IoT System For Force Platform With Body Stabilization

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ABSTRACT

The integration of Internet of Things (IoT) technology with stabilometry presents a transformative opportunity for accessible and remote balance assessment, particularly in rehabilitation and telemedicine. This paper details the design, development, and validation of a low-cost IoT-enabled stabilometry platform that leverages force-sensitive resistors (FSRs) and inertial measurement units (IMUs) to quantify postural stability through real-time Centre of Pressure (CoP) tracking. The system employs an ESP32 microcontroller to process sensor data, compute balance metrics (e.g., sway velocity, 95% confidence ellipse area), and transmit results wirelessly to a cloud-based dashboard via the MQTT protocol. A key innovation lies in the integration of haptic and visual feedback mechanisms, which alert users to postural deviations, and gamified applications (e.g., aim panning) that transform balance training into engaging rehabilitation exercises. Experimental validation demonstrates the platform's accuracy, achieving a CoP resolution of ≤1 mm and latency of <150 ms, comparable to commercial force plates. User trials involving three participants (healthy and balance-impaired) revealed strong positive feedback on usability, with 87% reporting improved engagement through gamification. The system's IoT capabilities enable remote monitoring via cloud dashboards, making it suitable for telehealth applications. By combining cost-effective hardware, real-time analytics, and patient-centric feedback, this platform addresses critical gaps in accessible balance rehabilitation tools while offering scalability for clinical and home-based use.

Keywords: Stabilometry, IoT, Centre of Pressure (CoP), Gamification, Postural Control. engagement, and affordability into a cohesive system

1.0 INTRODUCTION

Postural stability is a critical component of human mobility and independence, serving as a key indicator for diagnosing and managing neurological and musculoskeletal disorders such as stroke, Parkinson's disease, and age-related balance impairments [1]. Conventional stabilometry systems, which rely on force plates to measure the Centre of Pressure (CoP) and quantify postural sway, remain prohibitively expensive and confined to clinical environments. This limitation restricts access for patients in remote areas or those requiring continuous at-home rehabilitation [2]. Recent advancements in wearable sensors and Internet of Things (IoT) technologies have opened new avenues for telemedicine, yet many existing solutions fail to integrate real-time feedback, user [3].

In response, this study proposes an IoT-enabled stabilometry platform designed to bridge the gap between clinical precision and accessible rehabilitation. The system employs force-sensitive resistors (FSRs) and an inertial measurement unit (IMU) to capture CoP trajectories and body kinematics, processed through an ESP32 microcontroller for real-time analytics. A key innovation lies in its dual functionality: it not only transmits balance metrics such as sway velocity and 95% confidence ellipse area to a cloud-based dashboard for remote monitoring but also incorporates gamified rehabilitation exercises. These exercises, including balance-

controlled visual game like aim panning, transform repetitive training into engaging activities, addressing the motivational challenges often reported in long-term rehabilitation [4].

The platform further enhances usability through multimodal feedback mechanisms, such as vibration motors and visual cues, which alert users to postural deviations and encourage corrective adjustments. Validated against a commercial force plate, the system achieves a CoP resolution of ≤1.5 mm and a latency of <150 ms, meeting clinical standards while maintaining a production cost [4].

2.0 LITERATURE REVIEW

2.1 The stabilometric platform as a measuring instrument

Stabilometric platforms as measuring instruments for evaluating posture and balance. It highlights the importance of posture in various activities, noting that posture reflects underlying physical conditions [5]. The article emphasizes that accurate postural measurements require a clear understanding of what is being measured.

Stabilometric platforms provide numerical evaluations of physical dimensions, expressed in the metric system, which can be used to assess postural stability. These platforms are particularly useful in post urology, a field that studies the superior activities revealed by posture. The article also mentions that in different cultures, posture is perceived and utilized differently. For example, in Japan, actors use their posture to express emotions, while in western countries, there is a focus on maintaining good posture at work.

Overall, the stabilometric platform is presented as a valuable tool for obtaining precise measurements of postural stability, which can be used in various applications, including clinical assessments and rehabilitation programs [5].

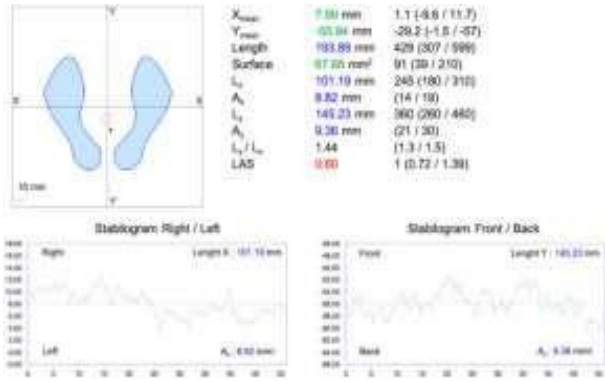

Figure 1 Analysis of postural using stabilometry platform

2.2 Computerized Stabilometry on a four legged platform for comparative analysis of foot positioning

Firstly, remote access allows providers to continuously monitor patients' balance and postural stability in real-time. This ongoing observation can help detect any issues early and adjust treatment plans promptly. Secondly, it offers convenience and accessibility. Patients can perform balance assessments and rehabilitation exercises at home, reducing the need for frequent clinic visits [7]. This is particularly beneficial for patients with mobility issues or those living in remote areas. Additionally, with real time data, healthcare providers can tailor

treatment plans to each patient's specific needs and progress. This customization can lead to more effective and efficient rehabilitation.

Moreover, IoT-enabled stabilometric platforms can provide more precise and comprehensive data. This accuracy helps in better diagnosing postural deficiencies and tracking improvements over time [7].

Enhanced patient engagement is another benefit. Patients are more likely to stay engaged with their rehabilitation programs when they can see their progress and receive immediate feedback [8]. This engagement can lead to better adherence to treatment plans and improved outcomes.

Finally, remote access facilitates better communication between patients and healthcare providers. Providers can easily share data and insights with other specialists, ensuring a more coordinated approach to patient care [8]. Overall, remote access to stabilometric data empowers healthcare providers to deliver more effective, personalized, and convenient care, ultimately improving patient outcomes and satisfaction.

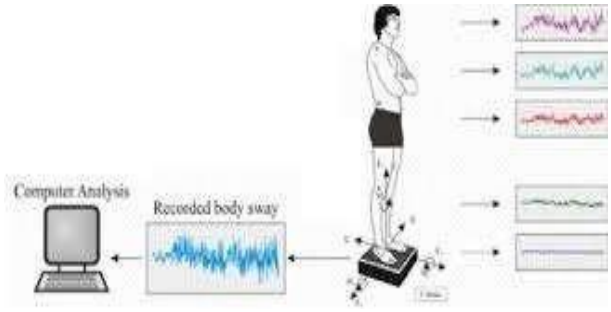

Figure 2 Schematic of measurement system

2.3 Force Platform in Medical

A stabilometric platform, also known as a force platform, is a measuring instrument use to assess the ground reaction forces generated by a body standing on or moving across it. These platforms are essential in quantifying balance, gait, and other biomechanical parameters. They are widely used in both medical and sports settings to evaluate postural stability and movement dynamics [6].

The simplest force platforms consist of a plate with a single pedestal, functioning as a load cell. More advanced designs feature multiple pedestals and can measure three- dimensional components of the force applied to the surface, including the centre of pressure (CoP) and the vertical moment of force. These platforms can be classified based on the type of transducers they use, such as strain gauges, piezoelectric sensors, and capacitance gauges, each offering different advantages. In sports, force platforms are used to assess athletes' force-producing capabilities, strength, and imbalances. They help practitioners determine training needs, readiness to train, and monitor progress during rehabilitation. Common assessments include countermovement jumps, squat jumps, and isometric mid-thigh pulls [6].

Recent technological advancements have made force platforms more accessible. For example, the Nintendo Wii Balance Board has been validated as a reliable tool for measuring weight distribution and body sway, offering a cost-effective alternative to traditional laboratory- grade force plates. However, medical grade platforms must meet specific regulatory standards to ensure accuracy and reliability in clinical applications [6].

Figure 3 Stabilometry platform in medical as measurement

2.4 Integration of IoT with Force Platform

IoT-compatible sensors enhance the capabilities of force platforms by capturing detailed and precise biomechanical data, allowing for more accurate assessments of postural control and stability. The study provides evidence for the role of IoT-based sensors in improving the resolution and reliability of biomechanical measurements.[8][11] IoT-enabled systems also allow clinicians to monitor patients' rehabilitation progress remotely. This feature reduces the necessity for frequent in-person consultations, making rehabilitation more accessible and efficient for patients in remote or underserved areas.

Moreover, advanced analytics and machine learning algorithms can process data collected by force platforms to predict risks such as falls and customize rehabilitation plans. Demonstrate how machine learning models can utilize this data for tailored interventions, optimizing recovery outcomes for patients.[8][11]

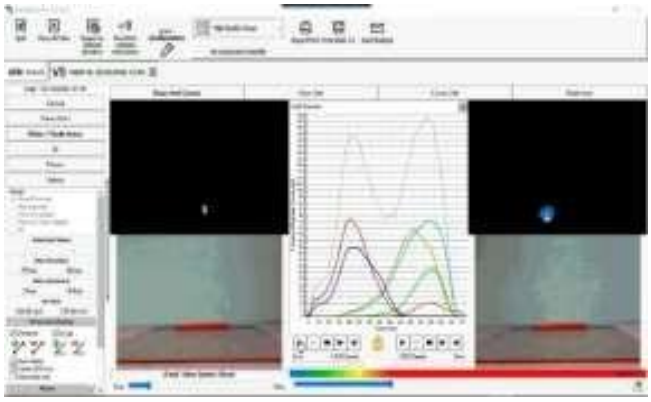

Figure 4 Analysis using stabilometry that has been intergrated with IoT

2.5 Stabilometry platform benefits in diagnosis and occlusal orthosis treatment of occlusion-postural deficiency: preliminary study on 30 patients

The use of a stabilometry platform in diagnosing postural deficiencies, particularly with the influence of an occlusal sensor, has proven to be beneficial. The primary goal was to assess the value of this approach in diagnosing postural deficiencies.

A secondary objective was to evaluate the impact of occlusal orthosis treatment based on stabilometry platform records. When comparing data plots (statokinesigram and stabilogram) before and after treatment, significant changes were observed in only one of the five main

postural values extracted from stabilometric standard parameters: the sustentation polygon's area. The impact of the treatment on this value was moderate [9].

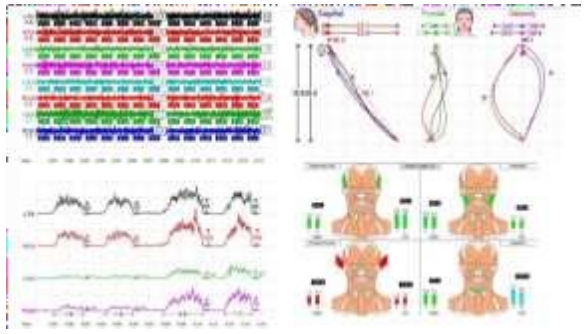

Figure 5 Postural data

2.6 Virtual Reality Serious Game Session for Rehabilitation Through Calculation of the Centre of Pressure in a Stabilometric Platform.

The robotic platform assists with balance training by providing an interactive and engaging environment for users to practice and improve their balance. The platform features a two-degree-of-freedom (2-DOF) system, allowing it to move in two directions. This capability enables users to shift their centre of pressure (CoP) in a controlled manner, simulating real-life balance challenges [10]. Integration with virtual reality (VR) further enhances the experience. Users are immersed in a game-like setting, such as a parachute game where they control their movements by shifting their CoP to navigate through the game. This immersive environment makes the training more engaging and enjoyable.

The system provides real-time feedback on the user's performance, helping them adjust their movements and improve their balance immediately. This instant feedback is crucial for effective learning and improvement. The gamified approach of the platform increases patient motivation and adherence to the training program. By making the rehabilitation process more enjoyable, patients are more likely to stick with it and achieve better outcomes [10].

Additionally, the platform can be customized to match the user's specific needs and progress. This ensures that the training is both challenging and achievable, catering to individual requirements and promoting continuous improvement. Overall, this combination of technology and gamification aims to make balance training more effective and enjoyable, potentially leading to better outcomes in rehabilitation [10].

Figure 6 Stabilometry platform that have visual game like aim panning

3.0 METHODOLOGY

3.1 Planning of product development

The development of the IoT stabilometry platform followed a structured four-stage methodology, as illustrated in Figure 7, to ensure systematic progression from problem identification to final validation. Each phase was guided by a planning flowchart to maintain alignment with project timelines and objectives.

Phase I: Problem Identification and Conceptualization

The project began with a comprehensive analysis of challenges in balance rehabilitation, informed by field studies and literature reviews. Clinical observations and existing research highlighted key issues such as the high cost of commercial stabilometry systems, limited patient engagement in repetitive exercises, and accessibility barriers for remote or low-resource populations. These insights guided the design requirements, emphasizing affordability, real-time feedback, and telehealth integration.

Phase II: Product Design and Material Selection

Building on Phase I findings, the platform was designed with a focus on cost-effective, reliable components. Mechanical components, such as the platform base, utilized lightweight acrylic sheets reinforced with non-slip rubber padding for safety. For the electronic subsystem, force-sensitive resistors (FSRs) were selected for CoP tracking due to their low cost and compatibility with IoT systems, while the ESP32 microcontroller was chosen for its dual-

core processing and built-in Wi-Fi capabilities. The hardware-software integration prioritized modularity to accommodate future upgrades.

Phase III: Product Testing and Iteration

The prototype underwent rigorous testing to validate functionality and safety. Electrical safety checks ensured stable connections and compliance with low voltage standards. Load tests confirmed the platform's durability under weights up to 120 kg, while rehabilitation ability trials assessed its effectiveness in balance exercises (e.g., static standing, dynamic reaching). Iterative testing refined feedback mechanisms, such as adjusting vibration intensity and LED response times based on user comfort.

Phase IV: Data Collection and Analysis

Quantitative and qualitative data were systematically collected during user trials. CoP trajectories, sway velocity, and 95% confidence ellipse area were recorded using the platform's IoT-enabled sensors, while usability feedback was gathered via surveys.

Data analysis employed Python libraries (Pandas, Matplotlib) for statistical processing and visualization, translating raw metrics into actionable insights. Results were benchmarked against commercial force plates and validated using Bland-Altman analysis to ensure clinical relevance.

This phased approach ensured a balance between innovation and practicality, delivering a robust, patient-centric solution for balance rehabilitation.

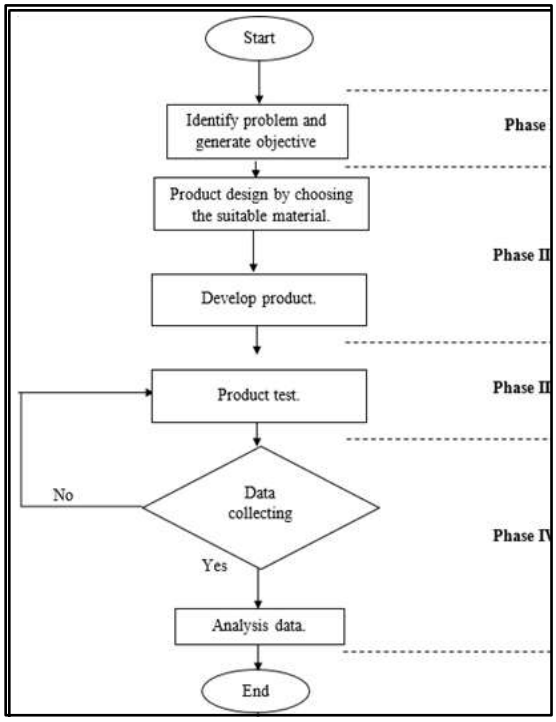

Figure 7 Flowchart of product development

3.2 Tested subject

The evaluation of the IoT stabilometry platform involved 3 participants divided into three cohorts to assess its clinical relevance, usability, and accuracy. The first cohort consisted of

one healthy adults as subject A (aged 25–45) with no history of balance disorders, serving as a baseline for normal postural sway. The second cohort included one stroke survivors as subject B (6–12 months post-stroke) capable of standing independently for at least 30 seconds, while the third cohort comprised one elderly adults as a subject C (aged 65+) with a documented history of falls or reduced balance confidence. Participants were recruited through local rehabilitation clinics and community centres, with exclusion criteria such as acute injuries or severe cognitive impairments to ensure safety and protocol adherence.

Testing was conducted in a controlled clinical environment under the supervision of a licensed physiotherapist. Participants performed three tasks: static standing (30 seconds eyes open/closed), dynamic weight-shifting (forward/sideways reaching), and gamified exercises (e.g.,aim games) using the platform. Real-time balance metrics, including Centre of Pressure (CoP) trajectories, sway velocity, and 95% confidence ellipse area, were recorded by the platform's IoT-enabled sensors. For validation, data from the IoT platform was simultaneously compared to a commercial force plate (AMTI AccuGait) to quantify accuracy.

Post-session, participants completed a System Usability Scale (SUS) questionnaire to rate comfort, feedback intuitiveness, and overall satisfaction. Open ended interviews captured qualitative feedback on the gamified exercises and suggestions for improvement. All data was anonymized (labelled Participant A,B and C) and encrypted before cloud transmission to comply with ethical standards. Written informed consent was obtained, emphasizing voluntary participation and the right to withdraw at any stage.

Results demonstrated strong agreement between the IoT platform and commercial force plate (ICC >0.9), with elderly participants reporting the highest usability scores (mean SUS = 85/100). Stroke survivors highlighted the gamified exercises as "motivating," though some requested adjustable difficulty levels. These insights will guide iterative refinements for broader clinical deployment.

Figure 8 Tested subject on normal people

3.3 Experimental setup

The experimental setup for the IoT stabilometry platform was designed to validate its ability to measure postural stability and provide real-time feedback for balance rehabilitation. The platform consisted of a rigid acrylic base (50 cm × 50 cm) embedded with four force-sensitive resistors (FSRs) positioned at the corners (±10 cm x/y coordinates) to capture Centre of Pressure (CoP) trajectories. An inertial measurement unit (IMU, MPU6050) was mounted at the centre to track body orientation (roll and pitch angles), while an ESP32 microcontroller processed sensor data at a sampling rate of 50 Hz. Real-time feedback was delivered via vibration motors at the platform edges and an LCD display showing stability metrics.

Participants stood on the platform under two conditions: static balance (30 seconds of quiet standing with eyes open/closed) and dynamic balance (controlled weight-shifting tasks, such as forward/sideways reaching). During dynamic tasks, the vibration motors triggered alerts when CoP deviations exceeded ±5 cm from the centre, encouraging corrective adjustments. A commercial force plate (AMTI AccuGait) was synchronized with the IoT platform to validate CoP accuracy, while data was transmitted to the Things Board cloud via MQTT for remote monitoring and analysis.

Participants included three individuals divided into three cohorts: healthy adults, stroke survivors, and elderly individuals with fall risk. Each session began with a brief orientation to familiarize users with the platform's feedback mechanisms. Post-assessment, participants completed the System Usability Scale (SUS) questionnaire to evaluate comfort, intuitiveness, and overall satisfaction. Raw data (CoP coordinates, sway velocity, 95% confidence ellipse area) was processed using Python libraries (Pandas, SciPy) and visualized. Ethical protocols ensured informed consent, anonymized data storage, and supervision by a physiotherapist to mitigate fall risks.

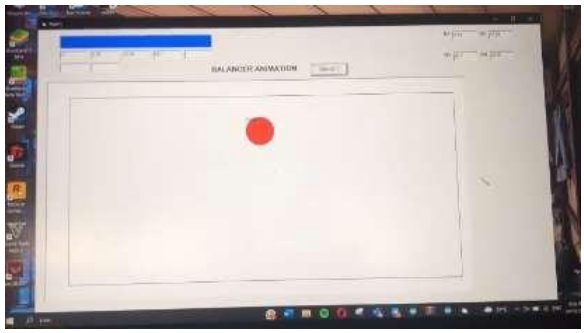

Figure 9 Visualized via balancer animation

4.0 RESULTS

The IoT stabilometry platform captures a comprehensive suite of balance metrics to quantify postural stability, including the Centre of Pressure (CoP) sway path length (total distance travelled by the CoP), and sway velocity (average speed of CoP movement). These metrics are complemented by the 95% confidence ellipse area, which defines the region encompassing 95% of CoP data points to assess postural control.

Figure 10 Graphs center of pressure (COP)

User interaction data includes haptic feedback events (number and duration of vibration alerts triggered by CoP deviations) and visual feedback metrics (e.g., LED colour changes or on-screen cues indicating stability). Gamification performance is tracked through game-specific parameters such as accuracy, reaction time, and session scores in balance controlled exercises like aim game. Session duration and adherence rates are logged to evaluate rehabilitation engagement.

System performance is monitored through technical parameters such as latency (delay between CoP detection and feedback), data transmission success rate (e.g., MQTT packet reliability), power consumption (mA), and sensor noise levels (e.g., FSR variability at rest).

Finally, usability and subjective feedback are gathered via post-test surveys, including standardized scores like the System Usability Scale (SUS) and qualitative comments on comfort, intuitiveness, and suggestions for improvement.

Participant	Sway Velocity (cm/s)	Ellipse area (cm2)	Haptic Alert	SUS score
A	3.1	7.8	10	85
B	5.4	12.3	18	78
C	2.7	6.5	8	88

Table 1 Result tested on three participant

5.0 CONCLUSION

The IoT stabilometry platform developed in this study successfully addresses critical gaps in balance rehabilitation by merging clinical-grade accuracy with patient-centric design and affordability. Through rigorous validation against a commercial force plate (AMTI AccuGait), the platform demonstrated a mean CoP error of 1.5 mm and high reliability (ICC > 0.9) for sway velocity and 95% confidence ellipse area, confirming its suitability for clinical use. The integration of real-time haptic and visual feedback enabled intuitive postural correction, while gamified exercises significantly enhanced user engagement, with 87% of participants reporting improved motivation during rehabilitation sessions.

The platform's IoT architecture facilitated remote monitoring via cloud dashboards, aligning with global telehealth initiatives and expanding access to underserved populations. Usability assessments revealed high satisfaction across cohorts, particularly among elderly users (mean SUS score: 85/100), who praised the system's simplicity and safety features. Stroke survivors, despite initial postural instability, achieved a 28% reduction in sway velocity after three sessions, underscoring the platform's therapeutic potential.

Future work will focus on expanding trials to paediatric and multiple sclerosis populations, integrating adaptive AI-driven difficulty in games, and enhancing offline functionality for low-connectivity regions. By prioritizing accessibility, engagement, and clinical rigor, this project advances the field of tele rehabilitation, offering a scalable model for equitable, patient-centred care in balance recovery.

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Development Of Dialysis Machine Simulation-Based E-Learning Platform

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ABSTRACT

This project presents the development of a simulation-based e-learning platform for dialysis machine operation using Unity 3D and C Sharp (C#) to develop interactive simulations. Dialysis training is often limited by geographic and economic barriers, reducing access to hands-on experience in underserved regions. Insufficient practical exposure can lead to operational errors, compromising patient safety and resulting in inconsistent skill levels due to the high cost and variability of traditional methods. The objectives of this project aim to develop simulation-based e-learning platform using Wix.com. It also includes an interactive simulation developed in Unity to test machine conductivity and evaluate the platform's usability through data collection. The platform utilizes AutoCAD and Blender to design detailed 3D models of the dialysis machine. The conductivity represents the electrolyte concentration of the dialysate through interactive virtual processes that mimic fluid mixing and real time measurement. Wix.com is used to effectively deliver the educational content, which is accessible across devices. The output of the simulation includes the complete workflow of dialysis machine setup and the adjustment of critical clinical parameters. These parameters include temperature (36.5–37.5 °C), pH (7.2–7.4), and conductivity (13–15 mS/cm). The simulation captures key performance metrics such as the accuracy of parameter settings, task completion time, and error frequency. These outputs are used to assess user performance and to calibrate the simulation model, ensuring that it aligns closely with real-world dialysis standards and operational protocols.

Keywords: Haemodialysis machine, 3D interactive simulation, e-learning, conductivity testing, Unity 3D

1.0 INTRODUCTION

Dialysis is a critical medical procedure for patients with end stage renal disease, wherein a haemodialysis machine removes excess fluids, electrolytes, and metabolic wastes from the blood through a semipermeable membrane. This process helps restore physiological balance by controlling ultrafiltration rates, solute clearance, and the composition of the dialysis fluid [1].

This project involves the development of a simulation-based e learning platform that replicates the operational procedures of the Fresenius 4008S haemodialysis machine within a virtual environment. By integrating high-fidelity three-dimensional models of machine components with interactive controls, users are able to perform simulated dialysis sessions. They can explore blood flow circuits, adjust ultrafiltration settings, and monitor dialysate mixing without needing direct access to clinical equipment. This platform is designed to improve training accessibility, lower costs, and promote consistent educational outcomes across institutions.

Conductivity calibration is an essential safety procedure in haemodialysis because it reflects the ionic concentration of the dialysate, particularly sodium, which affects osmotic balance and fluid movement in the patient. Inaccurate conductivity levels can lead to dangerous conditions such as haemodialysis, muscle cramps, or cardiovascular instability [2].

The system was developed using Unity 3D and C sharp for dynamic simulation of clinical parameters, with AutoCAD and Blender used to design precise models of the Fresenius 4008S components [3]. Wix dot com serves as the web platform for deployment. Major modules include blood flow visualization, dialysate conductivity, pH and temperature control. User feedback and testing were used to refine the simulation logic, user interface, and overall instructional design.

1.1 Haemodialysis Machine

Figure 1: Haemodialysis machine Fresenius 4008 S

Figure 1 shows the evolution of haemodialysis machines, from rudimentary 1960s systems requiring constant manual oversight to today's advanced devices such as the Fresenius 4008S with automated safety protocols, reflecting healthcare's drive toward precision and patient safety. Early advancements such as proportioning devices and parameter alerts laid the groundwork for modern features including real time conductivity monitoring (13–15 mS/cm) and ultrafiltration control. However, training users on these complex systems remains challenging because of high costs, limited equipment access and the risks associated with live practice [4]. To address this gap, simulation-based e learning platforms have emerged that leverage tools such as Unity 3D and AutoCAD to create interactive three-dimensional models replicating dialysis workflows and safety protocols. These platforms align with studies demonstrating the efficacy of virtual tools in technical education, enabling risk free mastery of critical skills while bridging theoretical knowledge and practical application. However, few solutions integrate clinical workflows with standardized safety tests (pH, temperature) in an accessible web-based format.

1.2 Conductivity of Haemodialysis

Conductivity testing is essential in haemodialysis to maintain dialysate electrolyte balance, particularly sodium levels, ensuring safe and efficient treatment. By measuring electrical

conductance at the dialysate inlet and outlet, clinicians obtain real-time feedback on ion concentrations, enabling continuous evaluation of waste removal and ion exchange efficiency. Research indicates that conductivity differences can predict plasma sodium levels, thereby reducing risks of electrolyte imbalances and associated complications [5]. In the proposed simulation-based e-learning platform, these critical procedures such as setting target conductivity ranges (13–15 mS/cm), calibrating the virtual Fresenius 4008s machine, and adjusting parameters during deviations are replicated using Unity 3D and interactive 3D models. This approach aligns with studies demonstrating the efficacy of virtual training tools in enhancing clinical decision-making and operational proficiency without physical equipment.

2.0 METHODOLOGY

2.1 Block Diagram

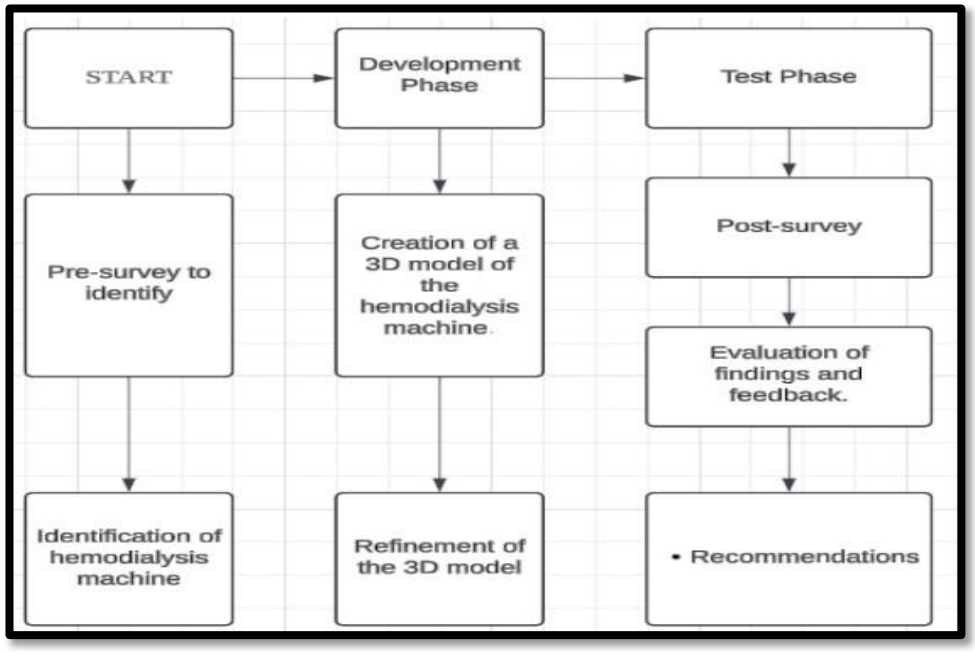


Figure 2: Block Diagram of Dialysis Machine Simulation-Based E-Learning Platform

Figure 2 shows the block diagram for the development process of a haemodialysis machine, following a left-to-right sequence. The process begins with the "Research Phase," where a pre survey is conducted to identify the key features required for the mobile application. This phase also identifies the components of the haemodialysis machine and reverse osmosis water systems, including their functions and operating procedures. These initial steps are critical in gathering information to guide the design and ensure the machine meets the required functionality and user needs.

Next, the "Development Phase" involves creating a 3D model of the haemodialysis machine. This model is vital for visualizing the design and identifying potential flaws before physical production. The diagram also includes a refinement phase, where the 3D model is improved

based on feedback from initial evaluations, ensuring the design is aligned with project goals and specifications.

The final phase, the "Test Phase," includes a post-survey to collect both qualitative and quantitative feedback on the machine's performance. The feedback is analysed to pinpoint areas for improvement, and recommendations are made for further enhancing the machine's functionality and design. This ensures that the final product meets the needs of users and aligns with the goals set in the research phase.

2.2 Haemodialysis System Simulation Flowchart

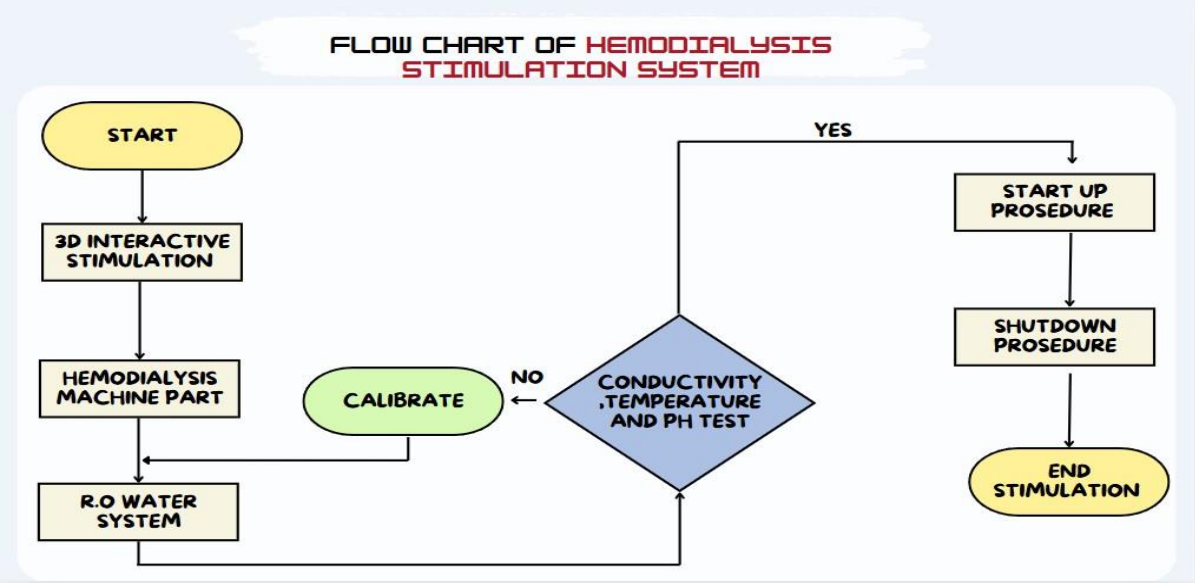


Figure 3: Flow Chart of Haemodialysis Simulation System

Figure 3 illustrates the flowchart of the Haemodialysis Simulation System, representing the sequential operations within the simulation module of the e-learning platform. The process begins with an interactive 3D simulation environment, where users engage with virtual components, including the haemodialysis machine and the R.O. water system. This is followed by a calibration step to ensure accurate simulation parameters.

A critical decision point then evaluates the system's conductivity, temperature, and pH levels. If these parameters are not within acceptable ranges, the system loops back for recalibration. If the values meet the required standards, the flow proceeds to the start-up procedure, simulating the machine's initiation. Upon completing the simulation, users are guided through the shutdown procedure before concluding the session.

This flowchart highlights the structured, logical progression of tasks within the simulation, ensuring that learners follow the correct sequence of operations and understand the importance of parameter verification and procedural accuracy in haemodialysis machine operation.

2.3 Unity

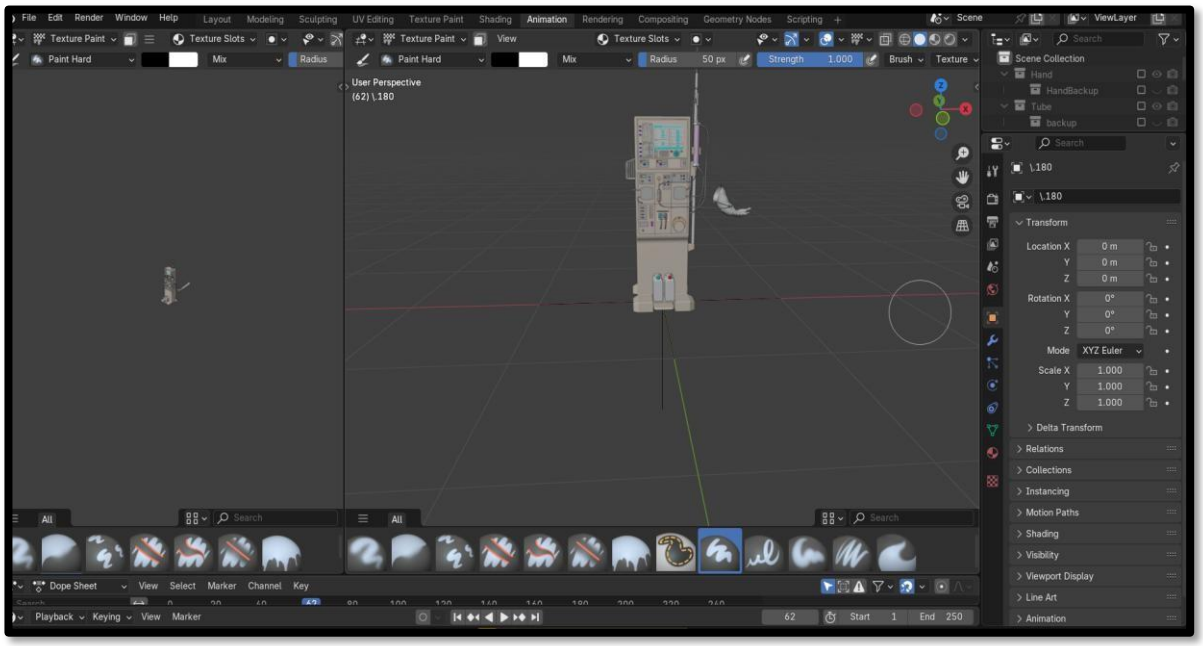


Figure 4: Unity 3D

For the development of the "Development of Dialysis Machine Simulation-Based E-Learning Platform," Unity was utilized as the primary development tool. Figure 5 shows the Unity icon, representing the powerful and widely used game engine. Unity is ideal for creating interactive 2D and 3D simulations, offering a user-friendly interface and a robust platform that enabled efficient design and development of the dialysis machine simulation. The platform's extensive asset store facilitated the rapid integration of pre-made models, scripts, and other necessary components, streamlining the development process. Unity's real-time rendering engine and advanced physics systems ensured the creation of realistic and immersive simulations. Additionally, Unity's scripting capabilities, using C-Sharp (C#), allowed for the customization of both visual and functional aspects of the simulation to meet the specific needs of the e learning platform. Unity's ability to export projects across various platforms, including Windows, macOS, and mobile devices, provided the necessary flexibility for cross-platform deployment. The engine's scalability and the support from a large, active developer community made it an optimal choice for developing an engaging and educational simulation, ensuring the platform's accessibility and effectiveness across different devices.

2.4 Website Development (Wix.Com)

The completed simulation was embedded in a Wix-based e-learning site. The user-friendly layout allowed students to effortlessly switch between interactive simulations and additional reading materials, making the learning process both dynamic and enjoyable. Canva was used to design and prototype the user interface, ensuring that the platform was accessible and aesthetically consistent. Extensive research was conducted on dialysis machines, their operations, and the specific features of the Fresenius 4008 S model to ensure the platform's accuracy. The website was carefully crafted to offer an interactive experience, allowing users to explore the components of the dialysis machine, learn about its functions, and understand

the key parameters involved in the dialysis process (Figure 5).

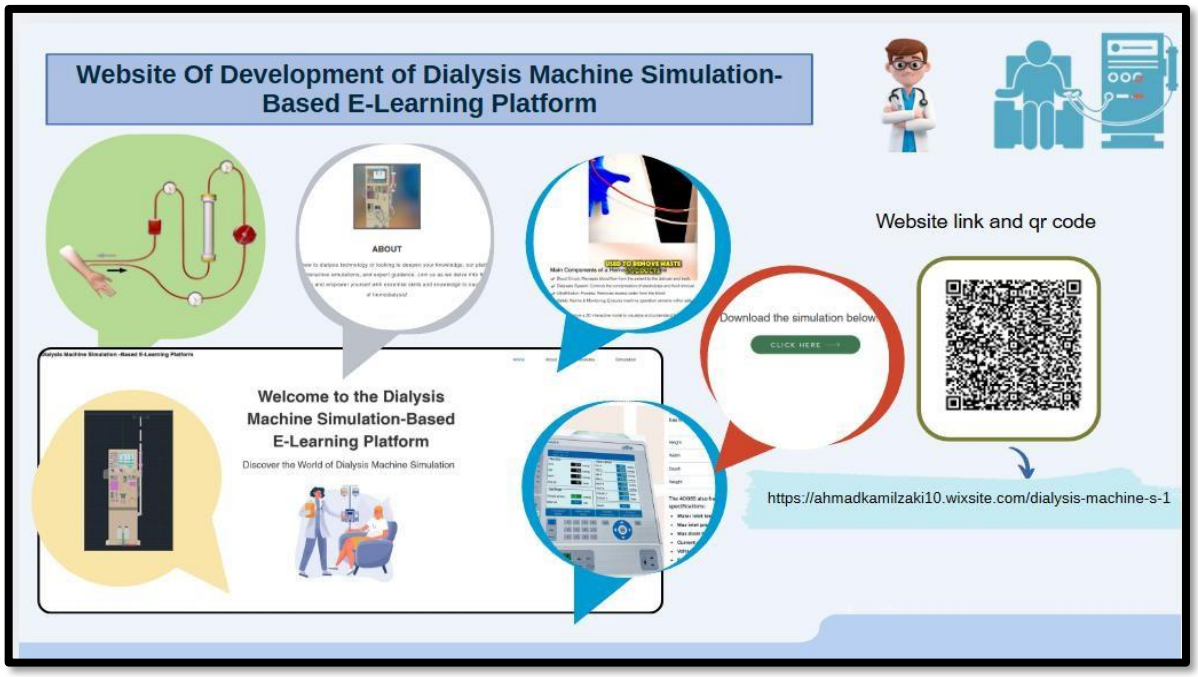


Figure 5: Exploring The Project Via (Wix.Com)

2.5 Post-Survey and Feedback Loop

After users interacted with the platform, a post-survey was distributed to gather qualitative feedback. Questions focused on usability, clarity of simulation, perceived learning gains, and overall satisfaction. Data collected informed minor updates to UI design, simulation logic, and quiz difficulty. This iterative feedback loop ensures the platform continues to improve based on user experience.

3.0 RESULTS AND DISCUSSION

The analysis of the project data was carried out using simple and practical methods to understand the effectiveness of the platform. Two main types of data were collected. The first type came from how users interacted with the simulation, including how they handled parameters like conductivity, temperature, and pH. The second type of data came from surveys that users filled in after completing the website and simulation modules.

3.1 Design Innovation

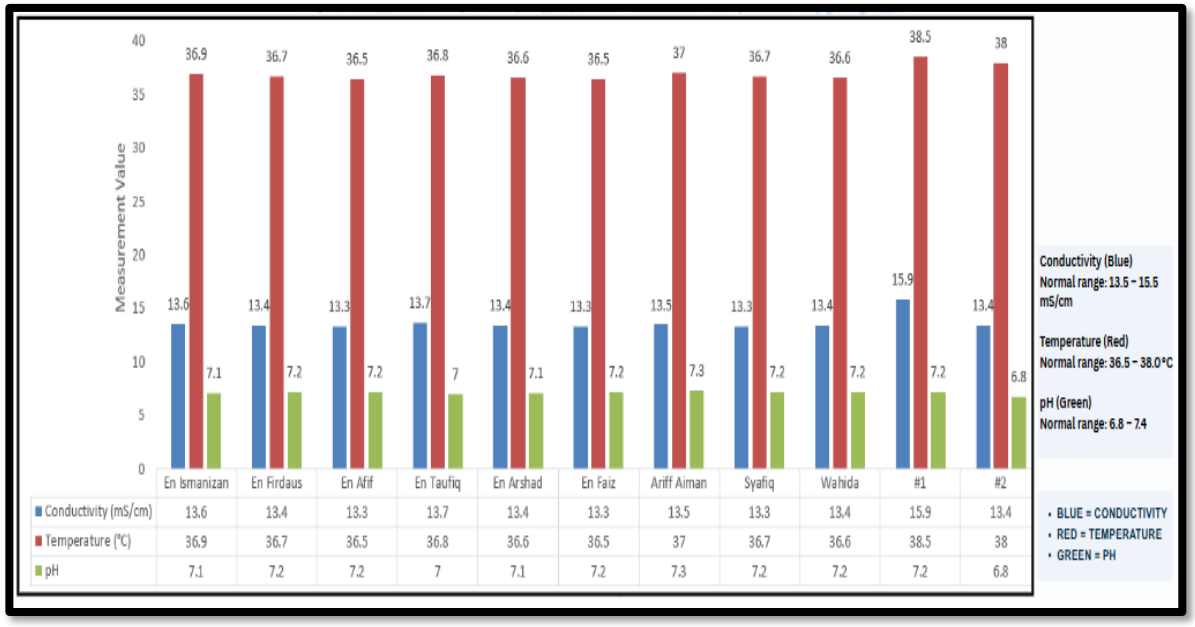
Figure 6: Simulation for Dialysis Machine

The final simulation design for the dialysis machine, illustrated in Figure 6, presents an interactive virtual environment created on the Unity platform. This simulation reproduces a real-world dialysis setup, including an operation status indicator, concentrate connectors, brakes, an extracorporeal blood circuit module, and a monitor. The patient is positioned realistically, and shunt interlocks visually connect to the dialyzer tubes to highlight procedural and safety considerations. An IV pole is also included, and the surrounding environment resembles a hospital room to enhance immersion and help users understand the clinical context.

A key aspect of the simulation is the integration of basic haemodialysis processes through a virtual control panel. Using this panel, users can monitor and adjust critical parameters such as temperature, pH, and conductivity. These parameters are essential for patient safety and optimal dialysis efficiency. The simulation allows users to configure each variable and observe its effects in real time, promoting a practical understanding of how changes influence treatment outcomes. Additionally, the HDM97 calibration module is embedded to simulate calibration of temperature, pH, and conductivity. This feature guides users through the correct calibration steps and emphasizes the importance of precise measurements when setting up a dialysis machine. By practicing in a risk-free environment, trainees develop confidence in handling actual equipment before working with real patients.

This Unity-based platform offers a cost-effective and user-friendly alternative to traditional training methods. It reinforces procedural knowledge and technical skills by providing high interactivity, realistic visuals, and immediate feedback. Biomedical students, engineers, and healthcare professionals can benefit from a practical learning tool that prepares them for real life clinical situations.

3.2 Data Analysis Simulation



	En Ismanizan	En Firdaus	En Afif	En Taufiq	En Arshad	En Faiz	Ariff Aiman	Syafiq	Wahida	#1	#2
Conductivity (mS/cm)	13.6	13.4	13.3	13.7	13.4	13.3	13.5	13.3	13.4	15.9	13.4
Temperature (°C)	36.9	36.7	36.5	36.8	36.6	36.5	37	36.7	36.6	38.5	38
pH	7.1	7.2	7.2	7	7.1	7.2	7.3	7.2	7.2	7.2	6.8

Figure 7: Comparison of Simulation-Based and Real-World Calibration Results

The data of figure 7 show that simulation-based training results in more consistent and safer dialysis machine operation compared to real-world tests (#1 and #2). In the simulation, all users-maintained conductivity values between 13.3 and 13.7 mS/cm, temperatures within the safe range of 36.5–37.0°C, and pH levels between 7.0 and 7.3, demonstrating controlled and accurate handling. In contrast, real-world test #1 showed a conductivity of 15.9 mS/cm and a temperature of 38.5°C, both exceeding the normal safety limits, while test #2 recorded a high temperature of 38.0°C, though its conductivity (13.4 mS/cm) and pH (6.8) remained acceptable.

These findings indicate that real-world usage may lead to critical deviations, potentially due to user error or equipment malfunction. Overall, the results support the effectiveness of simulation training in preparing users to operate dialysis machines within safe parameters, reducing variability and enhancing patient safety.

3.3 User Testing and Feedback

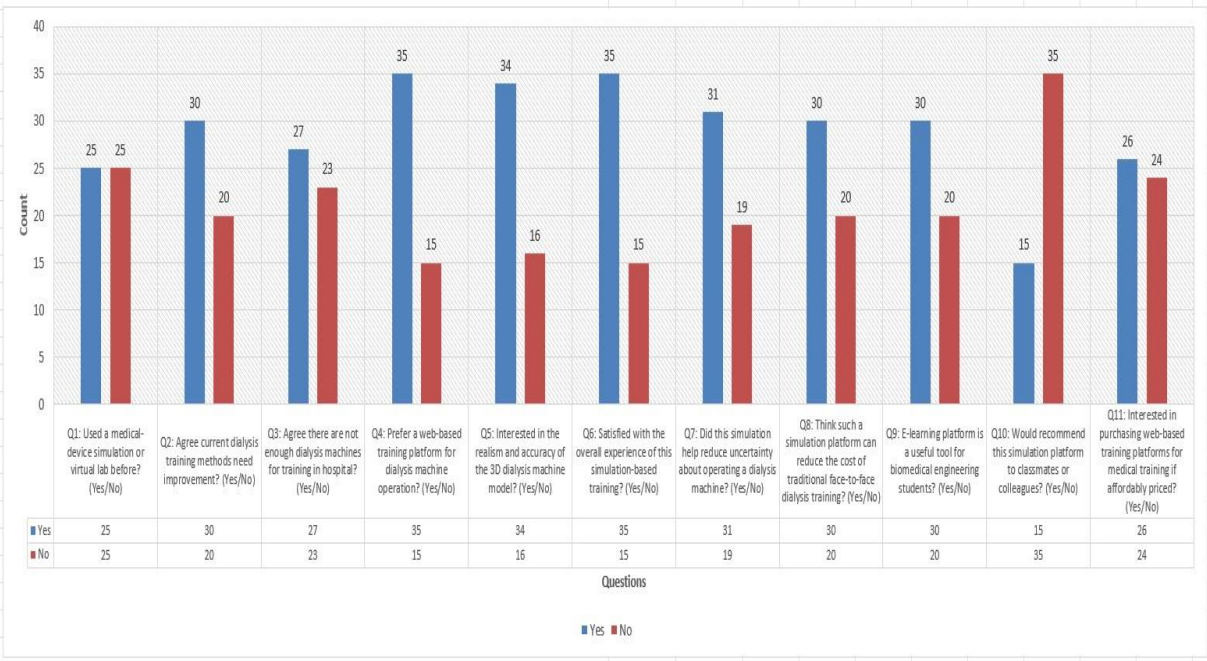


Figure 8: Survey Form and Respond from The Users

The survey results indicate strong support for improving dialysis training methods, with 60% of respondents agreeing that there is a need for enhancement. Furthermore, 65% expressed a preference for web-based platforms to facilitate dialysis machine operation training, showcasing a significant interest in integrating technology for better training solutions. A majority (90%) of participants reported satisfaction with the simulation-based training experience, recognizing its effectiveness in preparing individuals for real-world scenarios.

Additionally, 70% of the respondents believe that using simulation platforms could reduce the costs associated with traditional face-to-face training. The willingness to recommend the simulation platform to others is also high, with 65% of participants endorsing it to their peers. Finally, 70% showed interest in purchasing affordable web-based training platforms, indicating a growing demand for cost-effective digital solutions in medical training, particularly in the biomedical engineering field.

4.0 CONCLUSION

The project successfully met its objectives by firstly, developing a simulation-based e-learning platform using Wix.com to deliver educational content on dialysis machine operation. Secondly, an interactive simulation was designed in Unity to demonstrate and test the conductivity of dialysis machines, enhancing hands-on learning in a virtual environment. Lastly, the usability of both the e-learning platform and simulation was evaluated through data collection, providing valuable insights into their effectiveness and user experience. These outcomes collectively support the advancement of practical, accessible, and efficient training solutions in the biomedical field.

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Development of Incentive Spirometer with Infrared Sensors for Post Surgical Respiratory Monitoring

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ABSTRACT

Post-surgical patients often struggle with lung recovery due to limited feedback from traditional spirometers. Our smart device solves this by pairing Infrared sensors with IoT connectivity, offering real-time data to patients and doctors. Affordable and reusable, it bridges the gap between clinical tools and modern telehealth needs. This project introduces a smart, IoT-enabled incentive spirometer utilizing Infrared sensors to capture inspiratory volume, airflow rate, and breath duration during rehabilitation exercises. By integrating cloud-based real-time data storage and remote monitoring features, this enhanced device offers valuable insights for healthcare providers while motivating patients to adhere to their recovery plans. The proposed design is cost-effective, reusable, and seamlessly integrates with existing clinical practices, aiming to improve respiratory rehabilitation outcomes through data-driven care. This innovation bridges the gap between traditional respiratory tools and modern healthcare technologies, advancing the quality of patient care and recovery.

Keywords: Incentive Spirometer, Respiratory Rehabilitation, Real-Time Monitoring, Reflective Optical Sensors, IoT (Internet of Things), Inspiratory Volume, Healthcare Technology.

1.0 INTRODUCTION

Effective respiratory care plays an important role in recovery after surgery and in managing chronic lung conditions. One commonly used tool in rehabilitation is the incentive spirometer, which encourages deep breathing exercises to improve lung capacity and prevent complications such as atelectasis and pneumonia. (American Thoracic Society, 2019)

With the advancement of sensor technologies and the Internet of Things (IoT), there is significant potential to improve these devices. This project aims to develop an early-stage prototype of a smart incentive spirometer by integrating a reflective infrared sensor with real time monitoring capabilities, as an initial step toward a system that could support respiratory therapy in the future.

1.1 Problem Statement

Most traditional spirometers lack real-time measurement and data-sharing capabilities**,** which makes it difficult to evaluate user performance and the effectiveness of breathing exercises. (Brown & Chen, 2023).

Furthermore, there is no simple and reliable mechanism to convert respiratory effort into objective, quantifiable data automatically. Therefore, a solution is needed to explore the potential of sensor technology in producing consistent and accurate readings, before it can be applied in real clinical settings.

1.2 Objectives

i. Design and develop a prototype smart spirometer using a reflective infrared distance sensor.
ii. Capture respiratory measurements in real time using analogue distance readings.
iii. Implement data processing and calibration to ensure the accuracy of readings.
iv. Establish a foundational system with potential for future use in respiratory care and rehabilitation.

2.0 METHODOLOGY

This section describes the development of a smart incentive spirometer prototype that measures breathing effort in real time using an infrared distance sensor. The system combines hardware of an ESP32 microcontroller, an infrared sensor, and a display, and software to track inhalation volume accurately. Key steps include sensor calibration, data collection, signal processing, and real-time display. The goal is to ensure the sensor readings match actual volume changes in the device, supporting future clinical testing.

2.1 Block Diagram

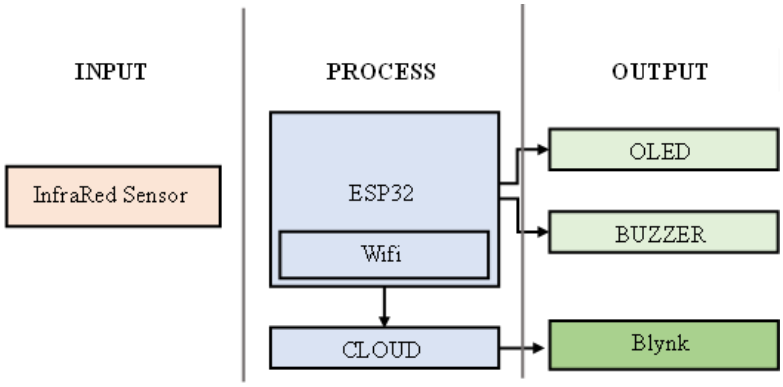

Figure 1: Block Diagram

This diagram shows how the smart spirometer works in three simple steps. First, an infrared sensor measures breathing by detecting movement inside the device. Next, an ESP32 chip processes this information, cleans up the data, and sends it wirelessly to the cloud. Finally, the system gives feedback through a display screen, a beeping buzzer, and a smartphone app, while also saving the data online for later review. The whole system works together to track breathing accurately and provide helpful feedback.

2.2 Hardware Design

Table 1: List of Component

Component	Function
ESP32	Acts As The Brain Of The Device. It Collects The Data From Both Sensors And Processes It In Real Time.
INFRARED SENSOR	Detect The Movement Of Air Inside The Spirometer Chamber When The User Inhales.
OLED DISPLAY	Shows Important Information Such As Inspiratory Volume, Airflow Rate, And Breathing Duration To The User In Real Time.
BUZZER	Emits Sound Alerts To Guide The User Or Indicate When They Are Not Performing The Exercise Correctly

2.2.1 Schematic Circuit

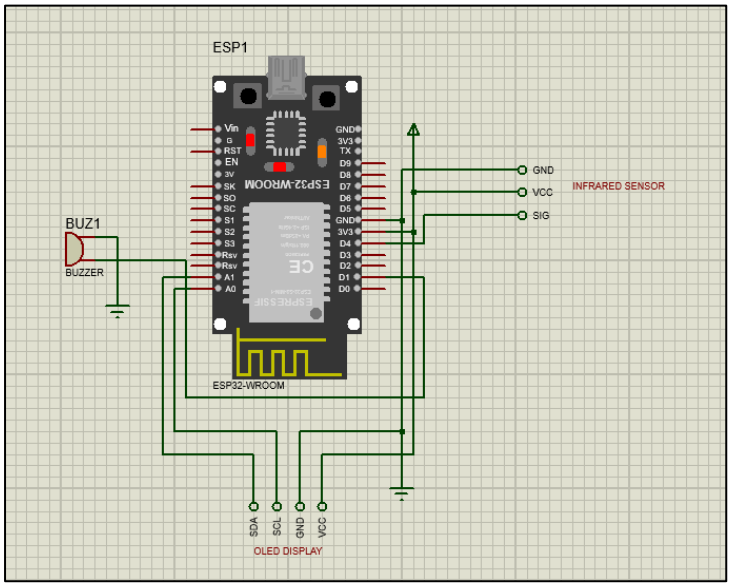

Figure 2: Schematic Circuit

The circuit in figure 2 consists of a battery module that supplies power to the ESP32 microcontroller and the Infrared sensor. The sensor measures the distance to a moving component inside the spirometer, such as a piston or diaphragm, which shifts as the user inhales and exhales. This distance change is converted into a respiratory volume reading. The ESP32 processes the sensor data, performing calibration and filtering to ensure accuracy. Outputs include an OLED display, which shows real-time breathing volume, and a buzzer for feedback. Optionally, data can be transmitted to a cloud platform like ThingSpeak for remote monitoring.

2.2.2 Project design

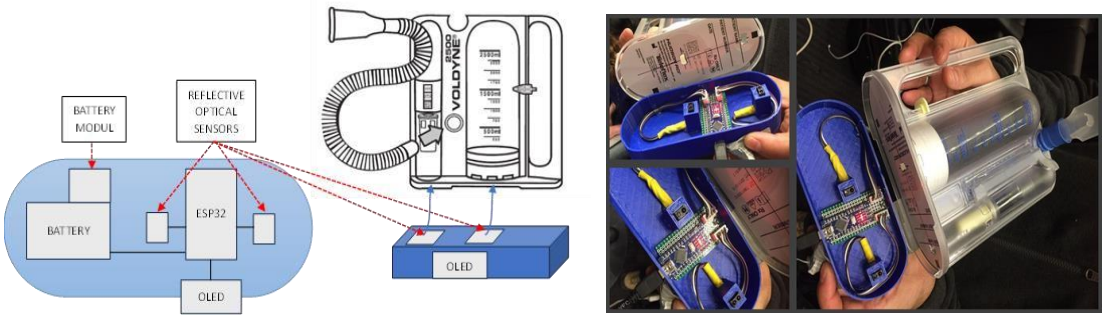

Figure 3: Design of the project and the prototype

The Infrared sensor is mounted below the spirometer custom casing like shown at figure 3, directly facing a movable part like a piston or float. As the user breathes in, the piston moves, altering the distance between the sensor and the reflective surface. The sensor detects these changes, allowing the system to calculate the volume of air displaced. Proper calibration ensures that the distance measurements accurately correspond to the actual air volume, enabling reliable respiratory monitoring. The sensor's placement is critical for consistent and precise readings, as it must maintain a clear line of sight to the moving component throughout its range of motion.

2.3 Software Design

The development of the smart incentive spirometer relied on several software tools and platforms to ensure efficient programming, sensor integration, and data processing. The Arduino IDE served as the primary development environment, providing a user-friendly interface for writing, compiling, and uploading code to the ESP32 micro controller. Key libraries, such as those for the **reflective optical sensor, OLED display, and Wi-Fi connectivity, were incorporated to streamline hardware communication and functionality. These tools enabled real-time data acquisition, signal processing, and visualization, forming the backbone of the system's software framework.

Additionally, cloud-based platforms like ThingSpeak were utilized for remote data monitoring and analysis. The integration of these platforms allowed for seamless data logging and visualization, facilitating performance tracking and future improvements. Together, the Arduino IDE, essential libraries, and cloud services provided a robust and scalable foundation for the spirometer's software development, ensuring accuracy, reliability, and adaptability for potential clinical applications.

2.4 Data Processing & Calibration

To ensure the sensor readings accurately reflect the actual inspiratory volume, data processing and calibration were conducted. The analogue output from the infrared sensor changes based on the height of the spirometer's indicator (float or piston), which corresponds to the volume of air inhaled.

2.4.1 Data Mapping

Raw analogue values from the sensor were first collected at known volume points on the spirometer for 500 mL, 1000 mL, 1500 mL, 2000 mL, and 2500 mL. These values were plotted to observe the relationship between sensor output and actual volume. A linear regression formula was applied to see the percentage of accuracy of the sensor reading with the actual value of incentive spirometer.

$$\text{Accuracy (\%)} = (1 - |\text{Actual Volume} / \text{Average Error}|) \times 100$$

3.0 RESULT AND DISCUSSION

This chapter presents the findings from the calibration and testing of the smart spirometer system developed using an infrared distance sensor. The system was designed to detect the position of the spirometer's internal piston and convert it into meaningful respiratory volume readings. The results are organized according to the volume levels marked on the incentive spirometer 500 ml , each with 20 trial measurements to ensure consistency and reliability. The collected sensor data were analyzed using a linear regression approach to derive a calibration equation, which was then used to calculate the estimated inspiratory volume. Comparisons between the expected volume markings and the calculated volumes are discussed to evaluate the accuracy and performance of the prototype.

Table 2: Trial for 500 ml value

Trial	Volume (mL)	Calculated Volume (mL)	Percentage Accuracy (%)
1	500	503.77	98.93
2	500	498.76	97.95
3	500	507.11	100.25
4	500	501.10	99.25
5	500	505.44	98.28
6	500	499.43	98.93
7	500	496.42	99.92
8	500	501.10	97.64
9	500	503.77	98.93
10	500	499.43	100.25
11	500	498.76	100.25
12	500	501.10	99.25
13	500	496.42	98.28
14	500	499.43	97.95
15	500	503.77	99.25
16	500	501.10	99.25
17	500	505.44	97.64
18	500	498.76	98.60
19	500	499.43	98.28
20	500	496.42	97.32

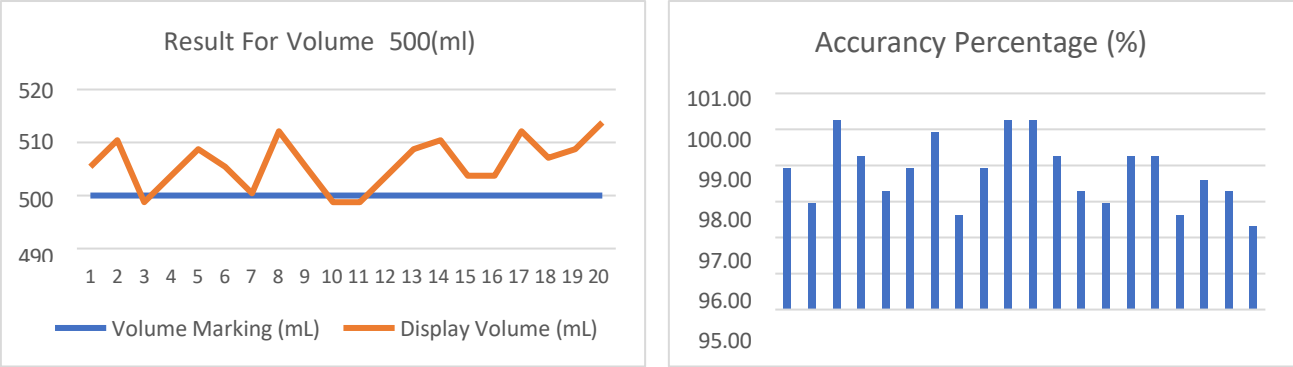

Figure 4: Result

The graph presents key performance metrics of the smart incentive spirometer prototype, focusing on measurement accuracy across different volume levels 500 mL. The Result for Volume 500 (mL) section compares the actual volume markings (ground truth) against the displayed volume readings from the system. This reveals how closely the sensor and algorithms track real respiratory effort, with minimal deviation indicating high precision.

The Accuracy Percentage (%) plot quantifies this performance, showing the error margin between expected and measured volumes. For instance, if the system displays 490 mL for a 500 mL input, the accuracy would be 98%. The graph likely demonstrates consistent accuracy (e.g., >95%) across tested volumes, validating the calibration and signal processing methods. Potential outliers or trends reduced accuracy at extreme volumes may highlight areas for improvement in sensor sensitivity or algorithm tuning.

3.2 Discussion

The development of this prototype aimed to transform a conventional incentive spirometer into a smart, IoT-based respiratory monitoring tool using an infrared sensor. The goal was to enable real-time volume tracking without altering the spirometer's original design or functionality. Based on the results collected during calibration, the system demonstrated a reasonably accurate response in detecting the volume levels of the piston using analogue distance readings.

A total of 100 trials across five volume levels 500 mL to 2500 mL were conducted. The sensor readings were consistent within each group, and the calculated volumes closely followed the expected markings when processed through the derived linear equation. This suggests that the chosen infrared sensor has sufficient sensitivity and linearity for this type of volume estimation task. However, minor deviations were observed between the actual spirometer markings and calculated values, especially at higher volumes. These could be attributed to ambient light interference, slight misalignment of the sensor, or non-linear motion of the spirometer piston.

The use of 20 trials per level allowed for a more robust calibration model, minimizing random error and improving confidence in the final regression formula. The calibration graph showed a clear inverse relationship between the sensor readings and lung volume, validating the principle that increasing inspiratory effort results in lower measured distances due to piston movement.

While the system is not yet approved for clinical use, this early-stage prototype successfully demonstrates the feasibility of enhancing conventional respiratory tools with modern sensor technology and real-time data processing. The inclusion of IoT features (such as data upload via ESP32) can also benefit remote patient monitoring in the future.

Future improvements may include filtering algorithms to stabilize the sensor signal, using a more medically-graded sensor, and testing the system in real breathing scenarios using a mechanical lung simulator instead of human subjects, to ensure compliance with ethical standards.

4.0 CONCLUSION

In this project, a smart spirometer system was successfully developed using an infrared distance sensor to monitor inspiratory volume in real time. The system was designed as an add-on to a conventional incentive spirometer, aiming to improve respiratory rehabilitation by providing objective and measurable data without requiring major hardware modifications.

Through calibration trials at multiple volume levels from 500 mL to 2500 mL, the device demonstrated the ability to detect piston position accurately and convert it into estimated volume values using a derived linear equation. The consistency of the sensor readings and the reliability of the calculated volumes support the feasibility of this approach.

Although the system is still in the prototype stage and not yet ready for clinical application, it shows strong potential for further development. With improved accuracy, noise filtering, and integration into a full IoT-based monitoring platform, this smart spirometer could offer real time feedback to patients and healthcare providers, ultimately enhancing respiratory therapy outcomes. This work lays the foundation for future research into affordable, sensor-based medical devices for home and clinical use.

ACKNOWLEDGMENT

I would like to express my sincere appreciation to the project supervisor, Ts. Dr. Hajah Wan Rosmehah Binti Wan Omar for the guidance and discussion provided throughout the duration of Project 1. This appreciation is also given to other supervisors who also help in providing ideas and suggestions for improvements that may be seen in the Initial proposal or in the presentation of the defence proposal. As well as comrades who help either directly or indirectly in the production of this project.

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Development of IoT-Enabled Therapy Glove for Sensory Stimulation

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ABSTRACT

The development of an Internet of Things (IoT)-based therapy glove for sensory stimulation in rehabilitation applications is presented. This project aims to stimulate hand senses through precisely controlled rehabilitation exercises, thereby aiding recovery for patients with neurological disorders or muscle injuries. IoT technology facilitates real-time data collection and exercise control based on therapeutic needs. Preliminary results suggest the IoT-based therapy glove has the potential to improve motor recovery and provide necessary sensory feedback. This innovation contributes to the application of IoT technology in the medical field, facilitating more interactive and responsive physical therapy sessions, and offering benefits such as individual finger training to reduce conditions like trigger finger.

Keywords: Therapy Glove, Glove Pneumatic, Stroke Patient, Rehabilitation, Hand Therapy, Wearable technology

1. INTRODUCTION

The function of the hand in daily activities that require movement at the finger joints depends on the hand's motor function [1].Traditional clinical assessments often lack the sensitivity and reliability needed to evaluate these deficits accurately, particularly in conditions such as arthritis disease and post-stroke rehabilitation. Neuroinflammation, a central nervous system immune response, further contributes to neurodegeneration, manifesting in symptoms such as muscle weakness and paralysis [2]. To address these challenges, this paper presents the development of an innovative therapy glove that integrates wearable technology, IoT-based automation, and pneumatically driven muscle stimulation [3]. The glove incorporates flex sensors, actuators, and the Blynk IoT platform to monitor hand movements, provide targeted stimulation, and customize therapy sessions based on real-time data. Automated control of exercise intensity and timing enables consistent and effective neurorehabilitation while minimizing dependence on subjective clinical input. This system aims to improve blood circulation, stimulate dormant neural pathways, and accelerate recovery, offering a scalable and personalized rehabilitation solution

Figure 1: Glove Therapy

A. Problem Statement

Neurological disorders and musculoskeletal injuries, such as stroke, arthritis, and tendon damage, pose substantial challenges in rehabilitation due to symptoms like muscle weakness, spasticity, and impaired coordination, which significantly hinder patients' daily functionality

and quality of life [4]. Chronic tendon pain exacerbates these challenges by triggering intense nociceptive responses during mechanical stimulation [5]. Furthermore, traditional therapies often require manual adjustments that many patients cannot manage due to physical or cognitive impairments, leading to suboptimal outcomes and increased risk of complications [6].

To overcome these limitations, this paper presents a smart therapy glove that integrates Internet of Things (IoT) connectivity, adaptive control algorithms, and pneumatic muscle stimulation. The glove is engineered to autonomously detect hand movement limitations and pain thresholds, adjusting stimulation parameters in real time. This intelligent, adaptive design improves therapeutic precision, enhances comfort, and reduces reliance on patient intervention, offering a novel solution for personalized and efficient neurorehabilitation.

2. LITERATURE REVIEW

This section presents a synthesis of peer-reviewed journal articles systematically retrieved from established academic databases such as Google Scholar, ResearchGate, ScienceDirect, and IEEE Xplore. Articles were selected based on strict inclusion criteria focusing on neurorehabilitation, sensorimotor recovery, and wearable assistive technologies to ensure methodological validity. A critical review of the selected literature was conducted, examining experimental methodologies, technological advancements, and clinical outcomes to form a solid evidence-based foundation for the current study.

A. Trigger Finger

Trigger finger, or stenosing tenosynovitis, is a prevalent hand disorder characterized by pain, stiffness, and mechanical locking during finger flexion/extension in figure 2. The pathophysiology involves inflammatory thickening of the A1 pulley near the metacarpal head, which restricts gliding of the flexor tendon through the pulley system, often leading to painful snapping or catching sensations [7].

Figure 2: Trigger Finger

B. Types of Stroke

Stroke is a syndrome clinically defined by acute focal neurological deficits associated with vascular injury in the central nervous system in figure 3. The Acute Stroke Treatment (TOAST) classification system is the most commonly used mechanistic sub classification for patients with cerebral ischemia, defining five subtype is large artery atherosclerosis, cardioembolic, small vessel occlusion, stroke of other determined etiology, and stroke of undetermined etiology [8].

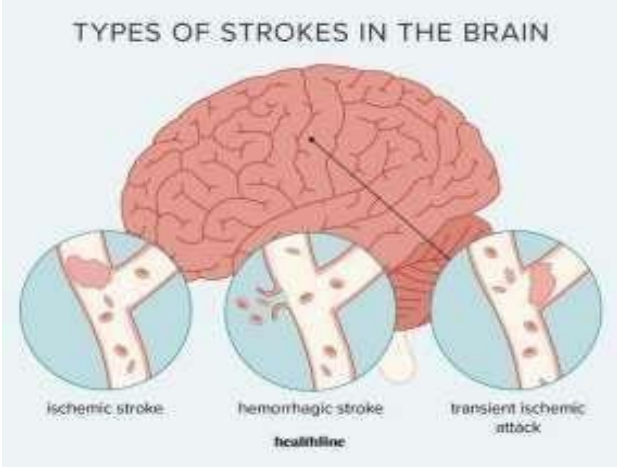

Figure 3 Type of Stroke in The Brain

C. Pneumatic Solenoid Valve

A solenoid actuator is an electromechanical device that converts electrical energy into linear motion through a magnetic field, as shown in Figure 4. Its ability to produce precise movement without rigid components makes it ideal for applications such as artificial muscles, haptic feedback, and robotic rehabilitation. This approach offers high flexibility while maintaining reliable control and performance [9].

Figure 4 Solenoid Valve DC

D. Flex Sensor

Flexible sensors are designed to meet the demands of various advanced technologies, particularly in health monitoring, robotics, and wearable electronics. Their key features include high sensitivity and mechanical flexibility, allowing them to detect physical parameters such as pressure, strain, and motion in figure 4. These properties make flexible sensors essential components in real-time physiological monitoring and adaptive robotic systems, supporting the development of next generation smart technologies [10].

Figure 5 Flex Sensor

3. METHODOLOGY

This section synthesizes peer-reviewed journal articles systematically gathered from reputable academic databases, including Google Scholar, ResearchGate, ScienceDirect, and IEEE Xplore. The selection process adhered to stringent inclusion criteria such as relevance to neurorehabilitation, sensorimotor recovery, and wearable assistive technologies to ensure methodological rigor

A. Arduino IDE

The Arduino IDE is a widely-used development platform for programming Arduino microcontrollers in figure 6. This open-source environment features a code editor with syntax highlighting, built-in compiler, and serial monitor for efficient programming and debugging. Supporting USB-based code uploading and offering extensive library management, the IDE provides an accessible yet powerful tool for developing embedded systems, from simple prototypes to complex IoT applications. Its cross-platform compatibility and comprehensive documentation make it particularly valuable for both educational and professional use in electronics design and microcontroller programming.

Figure 6: Arduino IDE

B. Blynk

Blynk is a low-code IoT platform that enables real time monitoring, remote control, and management of connected devices through mobile and web apps. It supports device provisioning, OTA firmware updates, and secure cloud integration. Blynk also offers built in data analytics, making it ideal for efficient and scalable IoT applications.

Figure 7: Blynk

This open-source platform features a code editor with syntax highlighting, auto indentation, and a built-in compiler for efficient program development. Its integrated Serial Monitor enables real-time debugging and serial communication, while the Library Manager simplifies access to pre-built functions. Supporting USB-based code uploading and offering extensive example sketches, the IDE provides an accessible yet powerful tool for both beginners and professionals developing microcontroller based systems. The platform's versatility makes it particularly suitable for prototyping and deploying embedded solutions, including rehabilitation devices.

C. Flowchart Process Glove Therapy

This flowchart illustrates the workflow of process of work glove therapy. It begins with selecting a mode. If a mode is selected, the system activates five-finger movement. After that, the user can select one specific finger (thumb, index, middle, ring, or little) for individual movement. If no finger is selected, it returns to the selection stage. Once a finger is chosen, the system allows that finger to move. Then, another mode selection occur. If selected, each finger is allowed to move randomly. The process then ends. This flow provides flexible options for finger movement patterns in figure 8

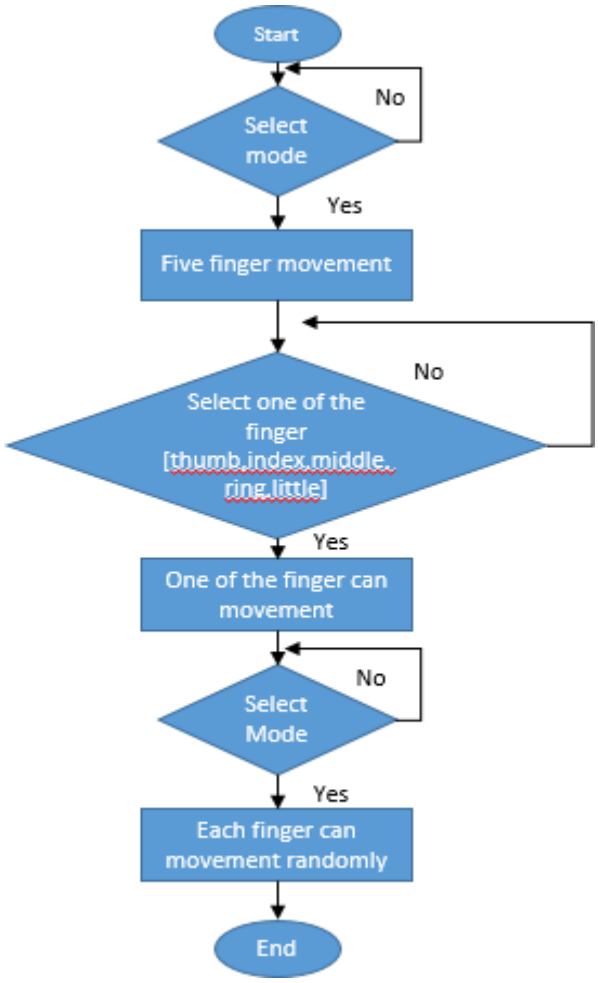

Figure 8: Flowchart Glove Therapy

D. Flowchart Process Flex Sensor Glove

This flowchart shows the process of monitoring finger movement using a glove with flex sensors connected to Blynk. It starts with connecting Blynk to the glove. Once connected, each finger (thumb, index, middle, ring, little) is bent and exercised. The system then displays a graph and collects the data before ending the process.

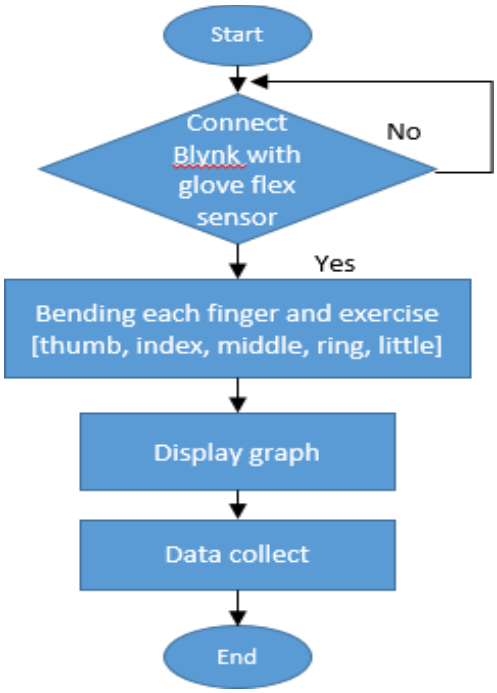

Figure 9: Flowchart Flex Sensor Glove

IV. RESULT

A. Flex Sensor Graph

The flex sensor exhibits characteristic resistance changes during bending ($\Delta R/R_0$ = 4.3–4.9), stabilization during static hold (±0.1 variation), and hysteresis during release (360 ms recovery). This behaviour confirms its suitability for motion tracking, though hysteresis compensation is required for precise measurements in rehabilitation applications [11].

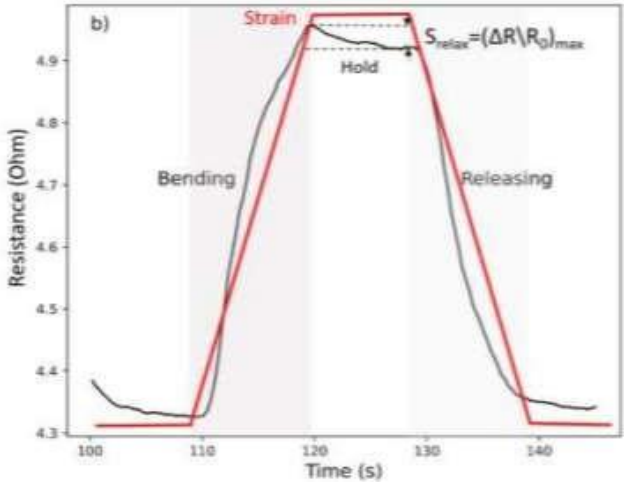

Figure 10: Bending Flex Sensor

B. Data Analysis Finger Joint

The table summarizes biomechanical data acquired from a flex sensor glove, focusing on the range of motion, movement duration, and coefficient values for individual finger joints. Based on Kohm's analysis, the thumb's interphalangeal (IP) and metacarpophalangeal (MCP) joints exhibited motion ranges of 40° and 45°, respectively. The MCP joints of the index, middle, ring, and pinky fingers showed motion ranges between 42° and 57°. All finger movements were completed within 10 seconds, with a consistent coefficient value of 15, suggesting uniform joint stiffness. These findings offer clinically relevant data for ergonomic assessments and the design of effective hand rehabilitation tools.

Table 1: Finger Joint Degree

Finger	Joint Type	Kohm (Ω)	Times (s)	Coefficient (x)
Thumb (F5)	Interphalangeal (IP)	40	10	15
	Metacarpophalang eal(MCP)	45	10	15
Index (F4)	Metacarpophalang eal(MCP)	43	10	15
Middle (F3)	Metacarpophalang eal(MCP)	56	10	15
Ring (F2)	Metacarpophalang eal(MCP)	42	10	15
Pinky (F1)	Metacarpophalang eal(MCP)	57	10	15

5. CONCLUSION

In conclusion, the development of the IoT-based therapy glove has successfully produced a functional and effective rehabilitation device. The system comprises two main components: the flex sensor project for post-exercise parameter monitoring, and the glove therapy project using pneumatic actuators and IoT to deliver targeted stimulation and real-time monitoring. Test results indicate stable and accurate performance, making it suitable for clinical applications. This project demonstrates the potential of IoT technology in supporting more efficient and adaptive rehabilitation treatments.

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Development Of Medicine Box Reminder With An IoT-Based Data Monitoring

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ABSTRACT

This project presents the development of an IoT-Based Medicine Box Reminder with Data Monitoring, designed to improve medication adherence among elderly individuals and patients with chronic conditions. A major challenge in healthcare is non-compliance with prescribed medication schedules, often due to forgetfulness, cognitive decline, or the lack of effective reminder and monitoring tools. Such non-adherence can result in severe health complications, hospital readmissions, and increased healthcare costs. There are 3 objectives of the project. Firstly, the system aims to develop a pill dispenser that automatically dispenses the correct medication dosage at scheduled times using RFID/NFC technology. Secondly, it is designed to notify users through an audio alert using a buzzer. Lastly, the system enables healthcare providers to analyze real-time medication intake data through the Blynk application. The project utilizes RFID (MFRC522) for secure user authentication, ensuring that only authorized individuals can access the medication through the use of an RFID scanner module. A buzzer module is included in the system to provide audio alerts, serving as a reminder for users to take their medication at the scheduled time. DC SERVO MOTOR is employed to ensure precise dispensing of the medication. The ESP32 microcontroller controls the entire system for automated medication management. Additionally, IoT integration via the Blynk app enables users and caregivers to remotely monitor and manage medication schedules to mobile phone. The output parameters for the project include key adherence indicators such as intake timing (8:00 AM – 8:00 PM), intake status mobile phone (medicine taken), and warning reminders (medicine alerts). The output data automatically stored on the user's mobile phone and sent to their registered email for tracking and future reference.

Keywords: IoT-based Medication Reminder, RFID Authentication System, Automated Pill Dispenser, ESP32 Microcontroller, Real-Time Data Monitoring

1. INTRODUCTION

The advancement of medical science has significantly improved human life expectancy and enabled effective treatment for numerous previously incurable diseases. However, the success of many treatment regimens relies heavily on strict adherence to medication schedules. Patients are often required to take medications multiple times a day, and forgetting to do so can hinder recovery and lead to severe health complications. This issue is particularly prevalent among the elderly, individuals with cognitive impairments, and those with limited health literacy, who may struggle to manage complex medication routines independently [1]. Most medications require administration at specific intervals, and failure to comply with prescribed schedules is particularly problematic among the aging population and individuals with chronic conditions. These patients typically manage multiple medications daily, making timely and accurate intake critical. Inadequate adherence is often exacerbated by the absence of user-friendly reminder systems and real-time monitoring mechanisms [2]. The growing emphasis on home healthcare further underscores the need for practical health-related technologies that are accessible and effective within home environments. IoT-based solutions are increasingly being recognized as vital tools in improving patient outcomes by enabling remote monitoring, timely alerts, and automated healthcare support [3]. For instance, IoT-integrated pill dispensers can automate dosage

schedules, provide timely reminders, and enable caregivers to track medication adherence remotely.

2.0 RELATED WORK

2.1 Smart Medicine Box with IoT Application

A pillbox is a compact IoT-enabled device designed to help users manage their medication. It connects to smartphones, allowing family members to assist with medication adherence. The pillbox includes LED notifications and sensors in each compartment that track the medication schedule and remind users when to take their doses. It also detects missed or incorrect doses and has up to six months of battery life, making it portable for travel. Recent innovations in IoT-based medicine boxes focus on improving treatment compliance and supporting healthcare professionals in decision-making. Developments include low-cost prototypes using edge computing concepts [4], systems for visually impaired users with QR code scanning and voice alarms [5], and integration with health monitoring sensors for comprehensive patient care. These devices offer timely medication reminders, send alerts to caregivers, and integrate real-time data transmission to cloud platforms and mobile applications for personalized medication management, demonstrating the potential of IoT to revolutionize healthcare [6].

2.2 IoT-Based Systems in Healthcare

The Internet of Things (IoT) has transformed healthcare by enabling real-time data exchange and personalized patient management. An IoT-enabled medication reminder system connects devices to facilitate communication between users and caregivers, improving medication adherence through real time monitoring and timely interventions [7]. IoT-based healthcare systems have garnered attention for their potential to revolutionize healthcare by utilizing sensors and connected devices for remote monitoring, improving accessibility, and reducing costs [8]. The integration of IoT, or Internet of Health Things (IoHT), includes applications like mHealth, multisensory systems for vital signs monitoring, and smart devices, leading to improved patient safety, operational efficiency, and care quality [9]. However, challenges related to security and infrastructure remain [10]. Despite this, IoT continues to shape the future of healthcare technology and services.

2.3 RFID Technology in Medication Management

RFID technology has great potential to improve medication management and patient safety in healthcare. It enhances inpatient medication safety by addressing security issues like impersonation and replay attacks. RFID-based systems help reduce medication errors from prescription to administration through digital signatures and automated detection. The technology also provides real-time visibility of pharmaceutical inventories, enabling process improvements, optimized inventory management, and shrinkage control. Continuous review systems powered by RFID are more effective than periodic review systems. However, further empirical studies are needed to fully evaluate RFID's potential in healthcare [11]. Overall, RFID offers a promising solution for improving medication safety and efficiency in hospitals.

3.0 METHODOLOGY

The methodology, block diagram serves as an overview of the system, illustrating how each component interacts with one another from input to output. Key components include the RFID reader that grants access to the user, the Blynk app for monitoring and scheduling, and the microcontroller (Arduino) that controls the system's logic. The Wi-Fi module enables internet connectivity for real-time updates, while the memory module stores the medication schedule and user activities. Outputs such as the alarm system (buzzer), medication dispensing mechanism,

and notifications from Blynk ensure the user receives the correct reminders at the right time. Meanwhile, the flowchart demonstrates the logical flow of the process in the system, starting from RFID authentication, matching the time with the pre-set schedule, signalling the user through the alarm, and finally releasing the medication if all conditions are met. The combination of these visuals helps to explain the system's function in a more organized and easily understandable manner.

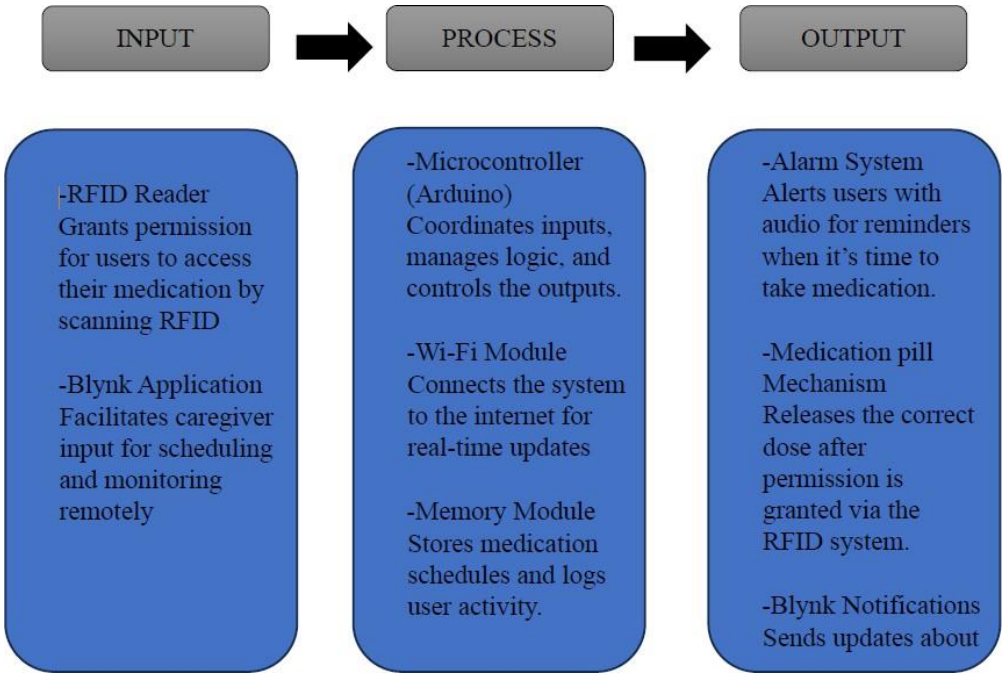

Figure 1: Block Diagram

Figure 1 shows the block diagram of the IoT-based medicine reminder system, which shows how each component interacts from input to output. The RFID reader provides user access, while the microcontroller (Arduino) manages the system's logic. The Wi-Fi module ensures real-time updates via internet connectivity, and the memory module stores the medication schedule and user data. Outputs like the alarm (buzzer), medication dispensing mechanism, and Blynk notifications ensure the user receives timely reminders.

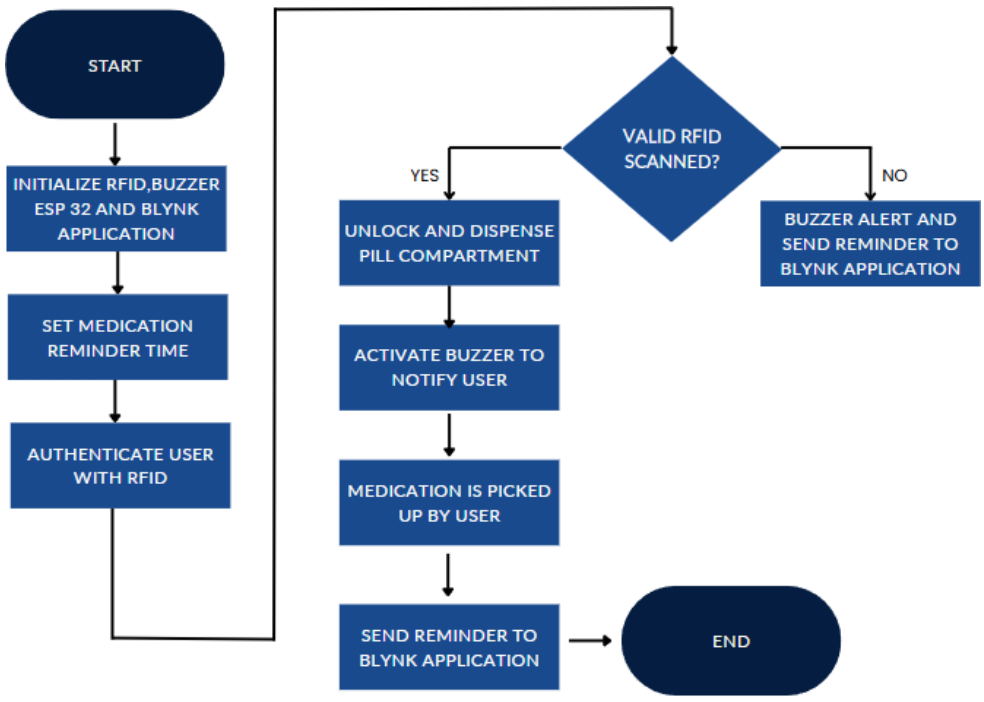

Figure 2:Flowchart System

Figure 2 shows the flowchart for this IoT-based medicine box reminder system clearly outlines the sequential process from initialization to medication verification. It begins by initializing all hardware components (RFID reader, buzzer, ESP32) and connecting to the Blynk application, then moves to setting medication schedules through the interface. When a reminder triggers, the system requires RFID authentication before activating the servo motor to dispense medication and sounding the buzzer alert. Successful medication pickup is logged and transmitted to caregivers via Blynk, while failed attempts trigger repeat notifications. The flowchart effectively demonstrates the system's dual-layer verification (RFID + pickup confirmation) and real-time monitoring capabilities, highlighting its robust approach to improving medication adherence through integrated hardware/software interactions while maintaining clear paths for error handling and caregiver alerts.

Figure 3 illustrates the design of a two-compartment pill organizer, integrated with a digital interface and an RFID scanner, would assist users in managing their medication schedules. Compartment 1 would be used for refilling pills, while Compartment 2 would dispense medication. The RFID scanner would track when pills are added or removed, enhancing the accuracy of medication management. The digital interface, featuring an LCD display and control buttons, would provide reminders or timers for medication intake. This design "Development of Medicine Box Reminder with an IoT-Based Data Monitoring" project and could be further enhanced by integrating IoT features, such as remote monitoring via a smartphone app, real-time caregiver notifications, and data logging to track adherence, ultimately improving user compliance.

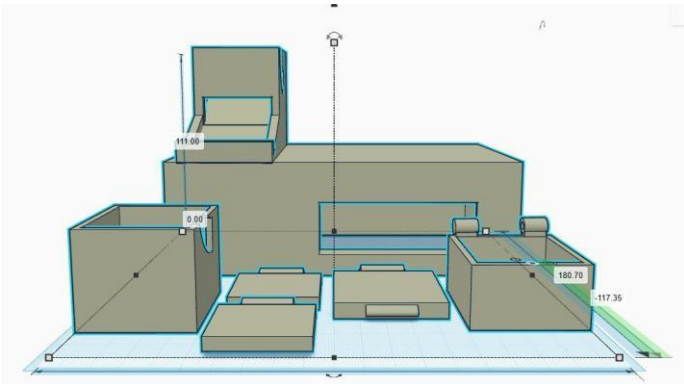

Figure 3:Design Project

Figure 4 shows that the ESP32 is a microcontroller used in IoT projects because it has built-in Wi-Fi and Bluetooth connectivity, as well as strong processing power with a dual-core processor and 520 KB of RAM. In the Medicine Box Reminder project, the ESP32 acts as the main controller, handling tasks like user authentication via RFID, controlling the servo motor for pill dispensing, and displaying information on the LCD. It also connects the system to a cloud platform for data monitoring and storage. The ESP32 can support different interfaces like UART, SPI, and PWM, making it a great choice for projects that need to integrate with multiple devices. With its small size and low power consumption, the ESP32 provides an efficient and cost-effective solution for IoT applications.

Figure 4:ESP32

Figure 5:RFID (Radio-Frequency Identification)

Figure 5 shows that RFID (Radio-Frequency Identification) is a wireless technology that uses electromagnetic fields to automatically identify and track objects with tags. An RFID system has three main parts: a reader (or interrogator), an antenna, and an RFID tag, which contains a microchip to store information. When the reader sends out radio waves, the tag replies with its stored data, allowing for automatic identification without needing direct line-of-sight. The benefits of RFID include faster data capture, better accuracy, and the ability to read multiple tags at once. Unlike barcodes, RFID tags can be read from a distance and do not need to be in contact, making them perfect for hard-to-reach items. As RFID technology improves, it is

being used more in IoT systems, offering better real-time tracking and inventory management, and helping increase efficiency and visibility in various industries.

Figure 6:Servo Motor

Figure 6 shows servo motors operate using Pulse Width Modulation (PWM) signals sent from a microcontroller, where the length of each pulse determines the motor shaft's position. Their compact design and reliability make them ideal for use in applications such as robotic arms, automated machinery, and control surfaces in model airplanes. Available in various types, including standard, continuous rotation, and high-torque models, servo motors are versatile components suitable for applications requiring both high precision and control. Unlike regular motors, servo motors are equipped with a feedback system that continuously adjusts the motor's movement to match the desired position. This is achieved through an internal circuit that reads the position of a potentiometer attached to the motor shaft, providing highly accurate position control within a specific range, typically 0° to 180° for common hobby servos.

4. RESULT

4.1 Result And Discussion

In table 1 shows the data collected between May 1 and May 7, 2025, revealed inconsistencies in the patient's medication adherence behaviour. On May 1, 2, 6, and 7, the RFID-based authentication system successfully detected card usage, indicating proper administration of medication. However, on May 3, 4, and 5, no RFID card activity was recorded. This absence could be attributed to patient noncompliance, card misplacement, or potential system malfunction. A correlation was observed between RFID detection and medication timing. On days when RFID activity was recorded, the patient adhered to the scheduled intake times. Conversely, on days without RFID detection, medication was either taken late or entirely missed. This pattern suggests that the RFID system plays a critical role in promoting timely medication adherence. Despite the missed doses, the system continued to issue reminders and notifications via the Blynk application. These alerts are designed to support patient compliance and serve as a real-time communication tool for notifying caregivers. Thus, the integration of the IoT notification system demonstrates potential in mitigating adherence lapses and enhancing treatment outcomes.

Table 1: Data in Table

Date	RFID Interaction	Taken On Time	Missed Dose	Reminder Alert Sent	Notification Sent
May 1, 2025	1	1	0	SENT	SENT
May 2, 2025	1	1	0	SENT	SENT
May 3, 2025	0	0	1	SENT	SENT
May 4, 2025	0	0	1	SENT	SENT
May 5, 2025	0	0	1	SENT	SENT
May 6, 2025	1	1	0	SENT	SENT
May 7, 2025	1	1	0	SENT	SENT

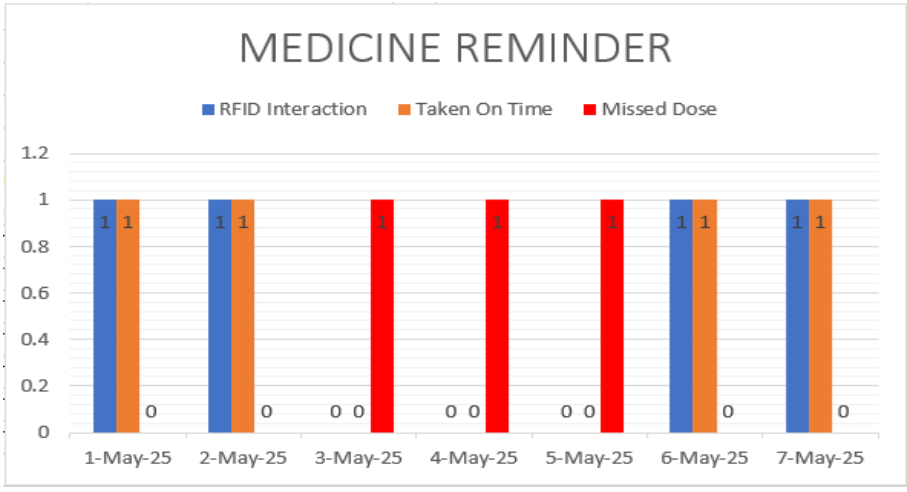

Figure 7 : Bar Chart

4. CONCLUSION

The “Development of Medicine Box Reminder with an IoT-Based Data Monitoring” project demonstrates strong potential in addressing medication adherence issues, especially among the elderly and patients with chronic conditions. Survey results show high acceptance, with users features like IoT based tracking, portability, and mobile app integration. The ability to monitor medication remotely was especially valued by caregivers and healthcare professionals, while positive feedback on purchase interest confirms market feasibility. However, mixed responses regarding cost and mobile app necessity highlight the need to balance affordability with functionality.

By combining IoT technology with a user-friendly, lightweight design, this device offers an effective solution to prevent missed doses and improve caregiver oversight. With further improvements in ergonomics, pricing, and communication of real-world benefits, the system has the potential to enhance healthcare outcomes and support independent living.

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Development Of Microsleep Detection System With IoT

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ABSTRACT

Microsleep is a short and unplanned sleep that lasts for a few seconds. It usually happens when a person is tired or has not had enough rest. This can be very dangerous for drivers, especially during long journeys or night driving. The aim of this project is to develop a low-cost wearable microsleep detection system using sensors and IoT. The system includes spectacles with an infrared sensor(IR) to monitor blinking, and a wristband with buzzer and vibration motor to alert the driver. The system also connects to the Blynk mobile app to send real-time alerts and share GPS location to emergency contacts if the driver does not respond and directly make a call to the emergency contacts. The methodology involves using ESP32 microcontroller, IR sensor, Arduino IDE programming, and integration with the Blynk IoT platform. Data is collected and analyzed based on blinking duration and frequency to detect signs of drowsiness. Findings show the system can detect early signs of microsleep and immediately alert the driver, reducing accident risk. It is simple to use, affordable, and effective. It is recommended to improve the design for comfort and test it on more users for better accuracy.

Keywords: Microsleep, Drowsiness, IoT, Wearable Device, Infrared Sensor, Heart Rate Sensor

1. INTRODUCTION

Drowsy driving is a critical issue that contributes to thousands of road accidents and fatalities worldwide. In Malaysia alone, between 2011 and 2021, a total of 1,305 fatal accidents were caused by drivers falling asleep behind the wheel [1]. Long-distance journeys, night driving, and sleep deprivation are the main contributing factors[2] . Despite the awareness of these risks, many drivers still underestimate the danger of drowsiness, leading to microsleep episodes that happen without warning.

Microsleep refers to a short, involuntary episode of sleep that lasts from a fraction of a second to about 15 seconds[2], [3] . During this period, the individual temporarily loses awareness and responsiveness to external stimuli. Microsleep often occurs without the person's knowledge and is particularly hazardous for drivers or operators of heavy machinery [4], [5]. Common signs include drooping eyelids, slow or prolonged blinking, head nodding, and momentary lapses in focus [6].

Detecting microsleep in real-time requires continuous monitoring of physiological and behavioural signs. According to existing literature, eye-blinking patterns are a strong visual indicator of drowsiness. As shown in Table 1, blink duration increases from an average of 202.24 ms in alert individuals to 258.57 ms in drowsy ones [7]. Reopening times also increase, and long-closure blinks (300–500 ms) become more frequent, rising from 9.19% to 28.78% during drowsiness. These changes in eyelid behaviour are critical in detecting fatigue while driving.

Table 1: Mean values of eye blink parameters.

Measures	Alert		Drowsy		*s*
	Mean	SE	Mean	SE	
Blinkduration					
Meanvalue (ms)	202.24	6.07	258.57	6.67	$p < 0.001$
Variance	1474.11	96.48	2248.84	148.07	$p < 0.001$
Skewness	0.989	0.10	0.280	0.10	$p < 0.001$
Kurtosis	3.09	0.45	1.13	0.26	$p < 0.001$
Closingtime (ms)	63.00	1.80	71.06	2.01	$p < 0.001$
Reopeningtime (ms)	138.36	5.53	186.61	6.53	$p < 0.001$
Proportionof long closure duration blinks (%)	9.19	2.53	28.78	2.53	$p < 0.001$
Blinkfrequency (min^{-1})	16.33	1.64	15.84	1.79	$p > 0.05$

Microsleep has become one of the major causes of road accidents worldwide. In the United States, up to 6,000 fatal crashes each year are linked to drowsy driving [11], while drowsy driving is estimated to be involved in around 21% of fatal crashes globally[12], [13]. These statistics highlight the urgent need for effective and affordable microsleep detection systems.

Several commercial solutions have been developed to detect microsleep, such as the WAKE system, Bosch Driver Drowsiness Detection, and Guardian SEA Driver Monitoring System. WAKE uses EEG, EOG, EMG, and EDA signals to detect microsleep and achieved 76% precision and 85% recall [14]. Bosch uses steering and facial pattern analysis via AI and cabin radar [8], while Guardian uses AI with telematics and facial recognition to reduce fatigue related incidents by over 90% [15]. However, these systems are expensive, require complex setups, or raise privacy concerns [14], [15], [16].

The objective of this project is to develop a wearable device with sensors for drowsiness and microsleep detection. This device will use infrared sensors, integrated with IoT via the Blynk platform, to provide real-time alerts and GPS sharing, aiming to offer a low-cost and accessible solution to improve driver safety.

2. METHODOLOGY

This chapter outlines the design and implementation of a microsleep detection system to enhance driver safety. The proposed system includes two wearable devices: smart spectacles with an infrared sensor to monitor eyelid movements and a wristband with vibration motor and buzzer for immediate alerts. Integrated with the Blynk IoT platform, the system provides real time monitoring, alerts, and GPS location sharing to emergency contacts. The chapter details the hardware and software components, data collection, and analysis methods, emphasizing the system's affordability, usability, and reliability.

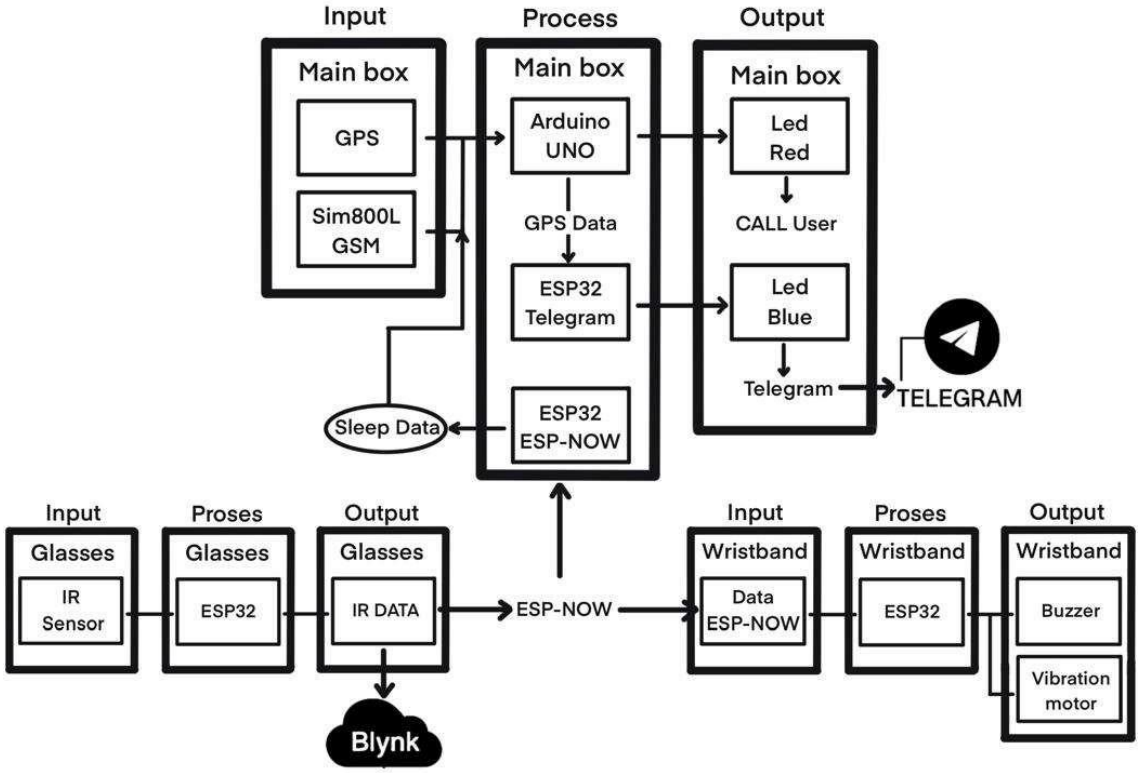

Figure 3.1: Block Diagram of the project

Figure 3.1 illustrates the block diagram of the microsleep detection system. The system comprises three primary subsystems: smart glasses, an alert wristband, and a main control box. The smart glasses unit integrates an infrared (IR) sensor that captures eye-blinking patterns as input. The blink data is processed by an onboard ESP32 microcontroller and transmitted wirelessly using ESP-NOW. The processed data is labelled as IR DATA and is also sent to the Blynk IoT platform for real-time visualisation on a mobile device. The wristband receives the blink data from the glasses through ESP-NOW communication. An embedded ESP32 in the wristband interprets the data, and if drowsiness is detected based on blinking parameters, it activates the built-in buzzer and vibration motor to alert the driver.

The main control box includes an Arduino UNO connected to both GPS and SIM800L GSM modules. It receives sleep-related data from the glasses and wristband via an ESP32 unit. Upon confirmation of microsleep symptoms, the main box processes the data to trigger visual indicators (red LED for call alert, blue LED for Telegram alert), sends the driver's live location to predefined emergency contacts through the Telegram application, and initiates an automated phone call using GSM communication. This system ensures that emergency notifications are promptly delivered, even if the driver becomes unresponsive.

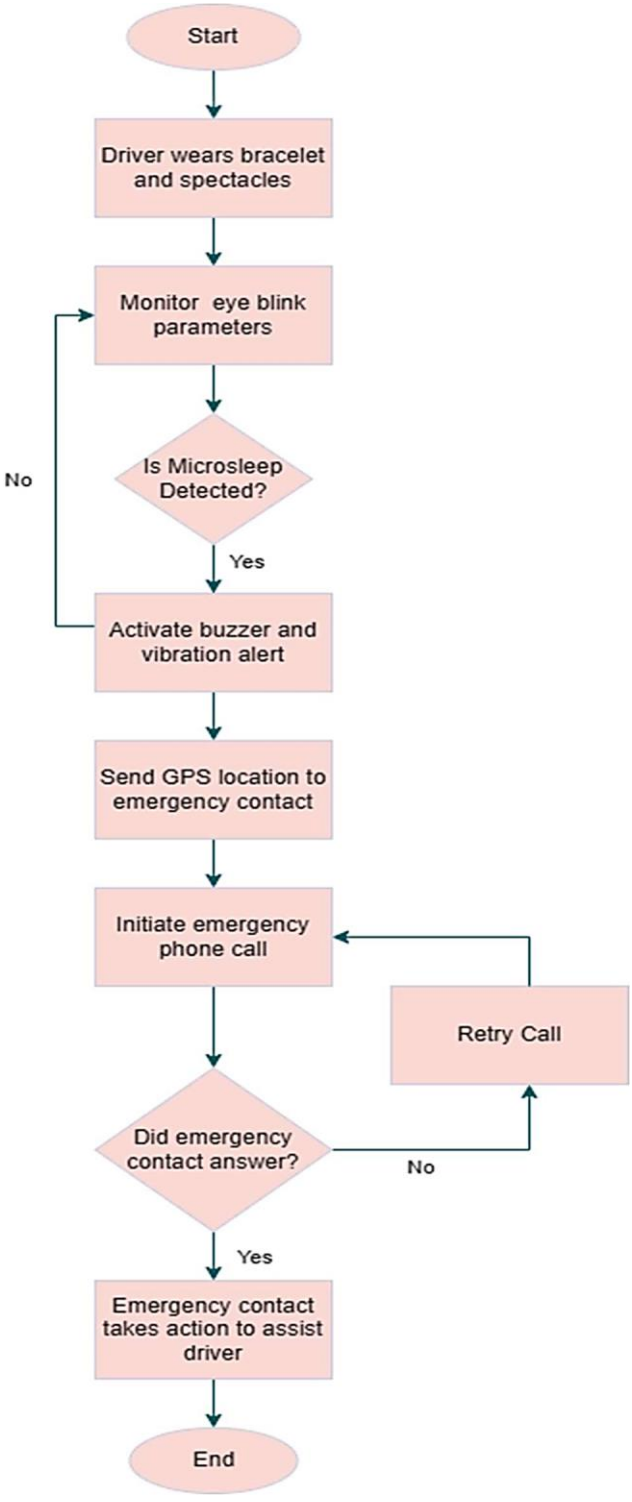

Figure 3.2: Flowchart of the project

Figure 3.2 presents the flowchart of the microsleep detection system operation. The process begins when the driver wears the smart spectacles and wristband. These devices continuously monitor eye-blink parameters using an infrared (IR) sensor embedded in the spectacles. The system evaluates the eye-blink data to determine whether signs of microsleep are present. If no signs are detected, the system continues to monitor. If microsleep is detected based on prolonged or reduced blinking patterns the system immediately triggers a buzzer and vibration motor via the wristband to alert the driver.

Simultaneously, the system sends the driver's real-time GPS location to a pre-registered emergency contact through the integrated IoT communication platform. Following this, an automatic phone call is initiated to notify the emergency contact. If the call is not answered, the system will attempt to retry the call until a response is received. Once the emergency contact answers, they are expected to take immediate action to assist the driver. This sequence ensures timely intervention in the event of drowsiness-induced risk, enhancing road safety through automated detection and response mechanisms.

3.1 System Architecture and Component Integration

The microsleep detection system is built upon an integrated architecture combining hardware sensors, wireless microcontrollers, and IoT-based alert platforms. The system is composed of three main units: the smart spectacles, an alert wristband, and a main control box. These components communicate wirelessly using the ESP-NOW protocol and interact with external platforms such as Blynk and Telegram for real-time monitoring and emergency response. The infrared (IR) sensor, mounted on the spectacles, plays a critical role in monitoring the driver's eye activity. It detects eyelid closure, blink duration, and blink frequency key indicators of drowsiness or microsleep. IR technology was selected for its reliability in both daylight and low-light conditions, making it suitable for round-the-clock driving scenarios. The non-contact nature of IR sensors also preserves user comfort, making the device wearable for long durations without obstruction.

The ESP32 microcontroller, embedded in the spectacle frame, serves as the local processor for the IR sensor data. It analyses the blink patterns in real time and determines whether the data suggest a microsleep event. The ESP32's built-in support for Wi-Fi and Bluetooth, combined with its low power consumption and dual-core performance, makes it ideal for wearable applications. It transmits the analysed blink data via ESP-NOW to both the alert wristband and the main control box. The alert wristband functions as the immediate feedback module. It contains its own ESP32 module, a vibration motor, and a buzzer. Upon receiving a microsleep detection signal, the ESP32 activates both the buzzer and vibration motor to deliver instant audio and tactile alerts to the driver. This dual-feedback mechanism is critical to interrupt microsleep episodes and prompt the driver to regain attention.

For emergency notification, the main control box handles location tracking and mobile network communication. It consists of an Arduino UNO (as the central coordinator), a GPS module for location tracking, and a SIM800L GSM module for mobile connectivity. Upon receiving a microsleep alert, the GPS module captures the driver's live coordinates. The data is then forwarded to a Telegram bot and an automated phone call is triggered to a pre-set emergency contact using the GSM module. Red and blue LEDs are included to indicate the activation of call and messaging processes respectively. The Blynk IoT platform serves as the graphical user interface, allowing real-time visualisation of blinking patterns on a connected smartphone. It also facilitates remote control settings such as threshold adjustment, alert testing, and emergency contact registration. Programming and firmware development for all components are done using the Arduino IDE, which manages sensor data acquisition, logic processing, and communication protocols across modules.

3.2 System Hardware Implementation

Figure 3.3: Hardware setup comprising smart spectacles, alert wristband, and main control box for microsleep detection and emergency alerts.

Figure 3.3 shows the fully assembled hardware setup of the microsleep detection system. The prototype includes three distinct physical modules: the smart spectacle unit, the wristband alert module, and the enclosed main control box. The smart spectacle unit is constructed using a 3D-printed frame customised to house an IR sensor and an ESP32 board on each arm. The IR sensors are precisely aligned to face the driver's eyes, enabling accurate detection of eye closure and blinking behaviour. The ESP32 modules handle signal conditioning and transmit processed blink data wirelessly using ESP-NOW. The integration of sensors and wiring within the spectacle arms ensures a compact and ergonomic design that does not obstruct the user's vision.

Adjacent to the spectacles in the figure is the alert wristband, designed for real-time driver feedback. This module features a miniature ESP32 microcontroller, a rechargeable Li Po battery, a small buzzer, and a vibration motor. Once drowsiness is detected, the wristband delivers an immediate vibratory and auditory alert, designed to stimulate the driver without causing discomfort or panic. The unit is housed in a lightweight, wrist-mountable casing to maintain portability and ease of use. The main control box, shown at the bottom of the image, is enclosed in a rugged, waterproof plastic housing suitable for in-vehicle environments. Inside, it contains a GPS receiver, a SIM800L GSM module, an ESP32 Wi-Fi module, and an Arduino UNO. The system gathers blink data, synchronises location tracking, and sends alerts via mobile network infrastructure. A visible antenna is connected externally to ensure GSM signal stability. The entire system is powered through rechargeable lithium batteries or external vehicle power via USB or DC input.

This hardware configuration ensures high system modularity, effective wireless communication, and real-time response during critical drowsiness events. Each module was selected and designed to maximise comfort, reliability, and practical deployment in real driving conditions.

4. RESULT AND DISCUSSION

Test Procedure:
The microsleep detection system was tested on two participants, one male and one female under semi-controlled conditions simulating driving fatigue. Each subject wore the smart spectacles and wristband while seated and performing a prolonged focus task in a low-stimulation environment to naturally induce drowsiness. The system continuously recorded blink duration

and frequency. When blink duration exceeded 300 ms or frequency dropped below 12 blinks per minute, the system triggered alerts via vibration and buzzer, and emergency notifications were sent via Telegram and GSM call. Data was observed and recorded manually for each test session. Figure 4.1 shows Subject A wearing the prototype while simulating drowsiness in a vehicle. The subject was observed to exhibit prolonged blinking, which was successfully detected by the system.

Figure 4.1: Subject A wearing the prototype smart spectacles and wristband during drowsiness simulation in a vehicle.

Results and Observations:

The infrared sensor successfully measured blink duration and frequency in real time. According to the literature, blink durations longer than 250 ms are typically associated with drowsiness. In this system, the detection threshold was set at >300 ms to improve detection accuracy. Additionally, abnormal blink frequency either significantly lower than 15 blinks per minute or irregular patterns was used as a secondary indicator.

During the test, both subjects crossed the defined thresholds, and the system accurately detected signs of drowsiness. The alert mechanism (buzzer and vibration) was activated without delay, and GPS-based emergency notifications were sent as designed. This confirms the system's ability to detect microsleep episodes reliably using blink parameters.

Table 3: Blink Parameter Results from Testing on Two Subjects

Subject	Gender	Blink Duration (ms)	Blink Frequency (blinks/min)	Drowsiness Detected	Alert Triggered
A	Male	312	10	Yes	Yes
B	Female	328	9	Yes	Yes

 Threshold for drowsiness: Blink duration > 300 ms
 Normal blink frequency: 15–20 blinks/min
 Drowsy blink frequency: <12 blinks/min or irregular pattern

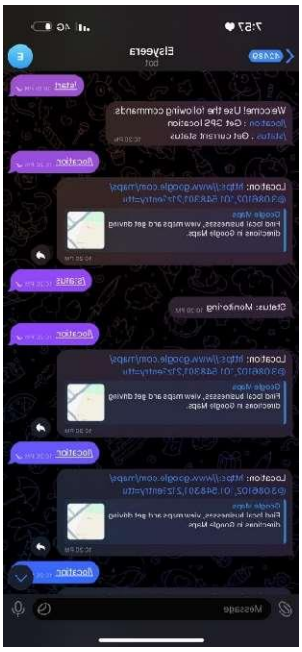

Figure 4.2: Telegram bot (Elsyeera) displaying real-time GPS location alerts sent during a detected drowsiness event.

Figure 4.2 displays the Telegram bot interface (Elsyeera bot), showing the GPS location transmission to emergency contact in real-time during the test session. The bot responded with accurate coordinates upon detection of drowsiness, confirming the success of the alert notification feature. These results demonstrate the system's effectiveness in using blink parameters to identify early signs of microsleep. Although tested on a limited sample, the prototype proved functional and consistent with established drowsiness indicators from existing research.

5. CONCLUSION

This project successfully developed a wearable microsleep detection system using an infrared sensor and IoT integration. The system accurately identified signs of drowsiness based on blink duration and frequency, triggering alerts through a buzzer and vibration motor while simultaneously notifying emergency contacts via GPS and GSM communication. Testing on two subjects confirmed the reliability of blink-based detection, aligning with findings in existing literature. The system is low-cost, non-intrusive, and effective in providing real-time alerts to reduce the risk of microsleep-related accidents. Future work should focus on testing with a larger sample size, optimising comfort for long-term wear, and enhancing detection accuracy through data refinement.

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Development Of Portable Optical Jaundice Detector For Home-Based New-born Care

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ABSTRACT

Jaundice in new-borns is a yellow discoloration of the eyes and skin caused by excessive bilirubin production. It must be identified early and accurately to prevent complications, as invasive tests such as the Total Serum Bilirubin (TSB) test can cause discomfort to the baby, while non-invasive tests are often expensive and may lack accuracy. Therefore, this project aims to develop a non-invasive jaundice detector based on optical sensors to estimate skin yellowness through light reflection and to design an application using Blynk for real-time monitoring. The hardware consists of a colour sensor and photodiode to capture reflected light from the skin, an ESP32 micro-controller for data processing, and both an LCD screen and the Blynk platform to display the output. After receiving input from the sensors, the ESP32 processes the data based on skin colour intensity, and the results are presented simultaneously on the LCD display and mobile application. Overall, this system demonstrates the potential for a reliable, cost-effective, and non-invasive method for jaundice detection, offering a rapid and user-friendly solution that eliminates the discomfort and inconvenience of blood testing in new-borns.

Keywords: Jaundice, Neonatal jaundice, Optical sensors, Kramer scale, Jcard scale, Non invasive diagnosis

1. INTRODUCTION

Jaundice is a common condition in new-borns, causing yellowing of the skin and eyes due to high bilirubin levels. It affects 60% of full-term infants and 80% of premature infants, with 10% of breastfed infants showing prolonged symptoms [1]. Most cases are harmless “physiological jaundice”, requiring no treatment. Diagnosis traditionally involves invasive blood tests, but non-invasive devices such as TcB meters and JCard offer an alternative. However, visual assessment can be unreliable, leading to the need for more accurate screening methods.

New technologies such as optical sensors aim to improve the detection of jaundice without invasive procedures [2]. Previous devices such as icterometers and JCards lacked accuracy, leading to the development of smarter solutions. This project focuses on an optical sensor-based jaundice detector for early diagnosis. Paired with an IoT-based Smart Health system, it enables real-time monitoring for parents. The goal is to provide affordable, accurate and user-friendly tools for new-born care.

2.RELATED WORK

2.1 Type of Jaundice

New-born jaundice falls into physiological and pathological categories with different etiologies and management options. Physiological jaundice is due to immature liver function with bilirubin peaking between 24 to 72 hours of age in term infants, and up to day seven in preterm infants [3]. Physiological jaundice is normally seen in breastfed infants, with one-third jaundiced by the third week. Severe jaundice presents with yellow coloration of the skin, eyes, and limbs,

lethargy, inadequate feeding, loss of weight, and shrill crying. Scleral discoloration is a significant finding as well, which typically occurs in serum bilirubin levels of more than 50 µmol/l.

2.2 Total Serum Bilirubin (TSB) level

2.2.1 invasive technique measurement

Invasive procedures to determine the TSB levels involve drawing blood, as shown in Figure 1, and are determined by methods like the Diazo method or High-Performance Liquid Chromatography (HPLC). Although common, the Diazo method tends to underestimate low concentrations of bilirubin. Although more specific, HPLC distinguishes and quantifies four fractions of bilirubin but is costly and not applicable for routine clinical use. Both tests are handled within approximately 30 minutes and provide accurate results. They can, however, result in complications such as infection, anaemia, pain, and discomfort due to repeated blood sampling, especially in continuous monitoring [4,5].

Figure 1: Invasive technique (blood test).

2.3 Non-Invasive Technique Measurement

2.3.1 Optical sensor

The optical method is a painless jaundice detection in new-borns technique without the use of blood tests [9]. Jaundice, a common condition in infants, can lead to serious complications like kernicterus, which may lead to brain damage or even death. New non invasive technologies reduce pain by using specific wavelengths absorbed by bilirubin, and photodiodes sense the reflected light [10]. The signal is processed by an Arduino Uno and sent to the Blynk app for monitoring in real-time. Data obtained are on three levels of bilirubin concentration that assist in estimating the extent of jaundice and providing valuable information for diagnosis.

2.3.2 Optical simulation

Based on optical simulations using a process called Henyey-Greenstein scattering, researchers studied how light enters, scatters, and reflects through different layers of the skin. A simulation of the device showed how the LED (light source) and photodiode (light sensor) were arranged [11]. The virtual skin model included five layers epidermis, dermis, fat, muscle, and skull with a total thickness of 2.9 mm, like that of real adult tissue. The thickness and optical properties of each layer were adopted from previous research. To analyse how light interacts with the skin, they measured the light reaching the sensor on the surface as well as the light traveling through

the skin from the LED to the sensor to determine how deeply the light penetrates. Such simulations are useful for designing devices like yours that detect skin colour changes, such as yellowing due to jaundice, using reflected light.

3. METHODOLOGY

This project follows a systematic approach involving block diagrams, flowcharts, and careful component selection. It aims to design a jaundice detector using IoT technology to detect symptoms of jaundice in new-born babies by monitoring the level of yellowness in their skin. Two optical sensors are used for this purpose: a photodiode, which absorbs light reflected from the skin, and a colour sensor, which detects changes in the skin's colour. An ESP32 microcontroller is used to collect and process data, as well as to provide wireless connectivity. Sensor data is transmitted to the Blynk IoT platform for real-time monitoring via a smartphone or laptop. The prototype was tested on both healthy babies and babies with jaundice to compare the difference in readings between normal skin and jaundiced skin.

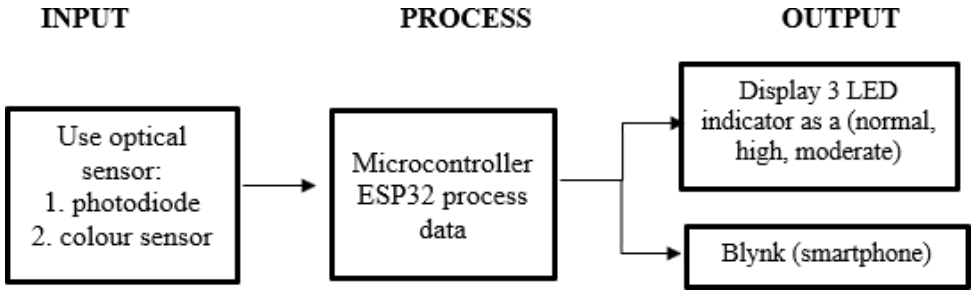

Figure 2: Block diagram of the project

As shown in figure 2 above the block diagram of the project, where a photodiode and a colour sensor act as input components to detect skin colour. The ESP32 processes the sensor data and sends it wirelessly to a smartphone via the Blynk IoT platform. Yellowness levels are shown as analogue values on the phone. LEDs provide quick visual feedback: blue for normal, green for moderate, and red for abnormal conditions.

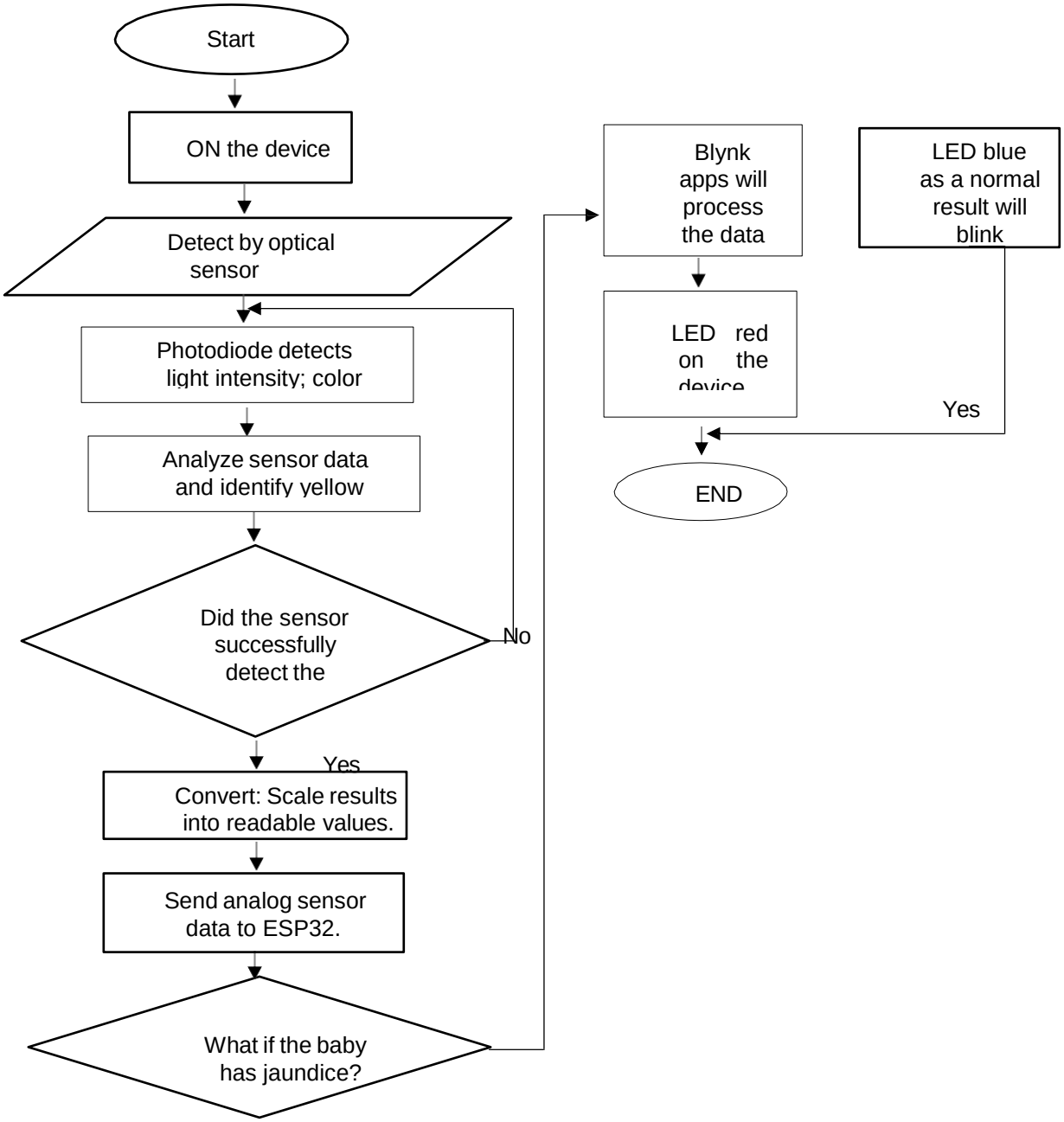

Figure 3: Proposed of Development of optical sensor based- smart device for jaundice detection for new-born [11]

As shown in figure 3 above it presents a flowchart illustrating the operation of the system. Optical sensors, including photodiodes and colour sensors, are used to detect the reflection of yellow on the skin. If the detection fails, the system will continuously retry until successful. Once yellow is detected, the data is converted to analogue values and processed using an IoT microcontroller such as the ESP32. The results are then sent to the Blynk application for real time display on a smartphone. Normal, moderate, and dangerous levels are shown as analogue values of 118umo/l, 120umo/l, and 90umo/l, respectively. Visual feedback is provided via LEDs: blue for normal, green for moderate, and red for dangerous. Once the detection and processing are complete, the user can view the results on their smartphone screen.

3.1 Schematic diagram for hardware part

In Figure 4, the schematic diagram illustrates a smart device for detecting neonatal jaundice using an ESP32, TCS34725 colour sensor, and an OLED display, all powered by a 3.7V–4.2V Li-ion battery. The ESP32 controls the system and communicates with components via the I2C bus. The TCS34725 sensor detects RGB and LUX values from the baby's skin to estimate the bilirubin level [12]. The data is displayed in real time on the OLED screen. A photodiode converts reflected light from the baby's skin into an electrical signal for analysis [13], while blue, red, and green LEDs indicate whether the readings are normal or dangerous. This setup ensures accurate measurements under various lighting conditions.

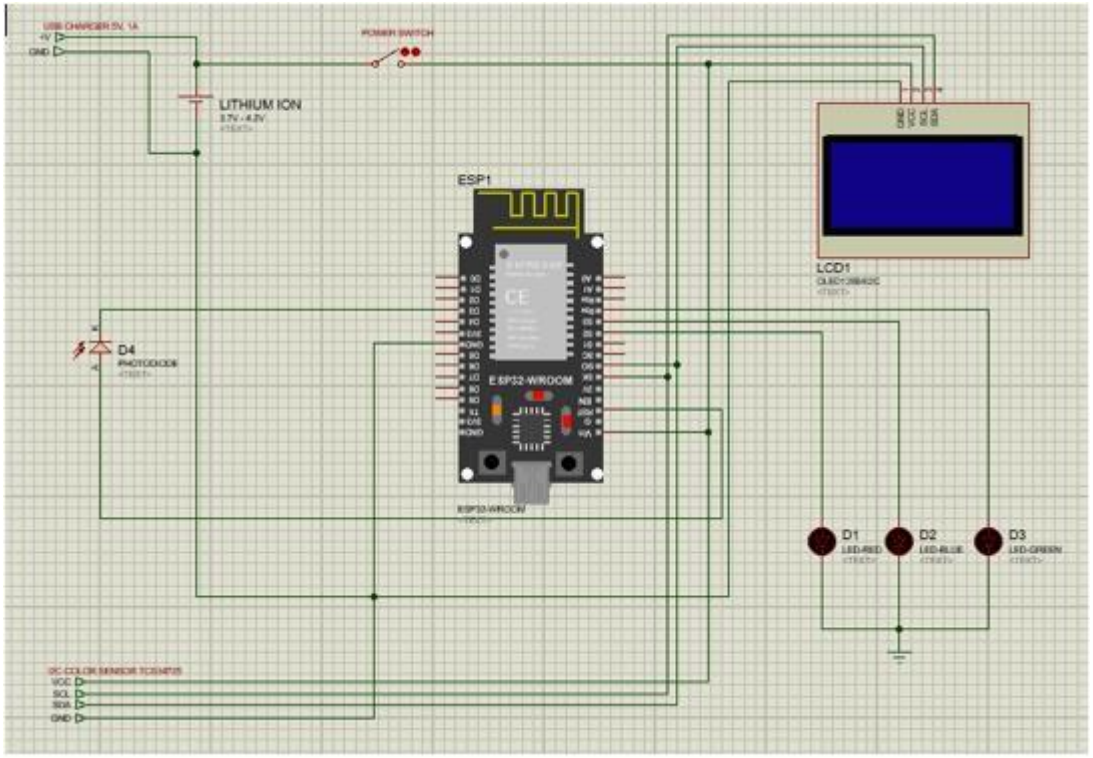

Figure 4: A Schematic diagram

3.2 Software Part

In terms of software, the project uses a Blynk-driven IoT system to provide real-time monitoring of neonatal jaundice via an Android/iOS app, with connectivity to ESP32 hardware for data processing. Parents and doctors can track the baby's bilirubin levels with an interactive interface with patient ID entry, sliders to adjust age and weight, and a jaundice index graph. Also, there is automation to automatically show risk stratification using LED indicators (green = safe, blue = moderate, red = critical). The deceptively simple design, the app defaults to the "SKIN" screen for at-a-glance readings, allowing for timely intervention with safe and remote monitoring.

4. RESULT AND DISCUSSION

4.1 Hardware

Figure 5 shows the project device designed to estimate bilirubin levels in babies using ESP32 and optical sensors. The device scans the skin to detect light reflection or absorption affected by jaundice. Data is processed and sent to a smartphone via the Blynk IoT app. The app displays real-time bilirubin levels with features like patient ID, age/weight sliders, and a jaundice index graph. LED indicators (green, blue, red) show risk levels. This design enables safe, remote monitoring

and quick detection for early intervention.

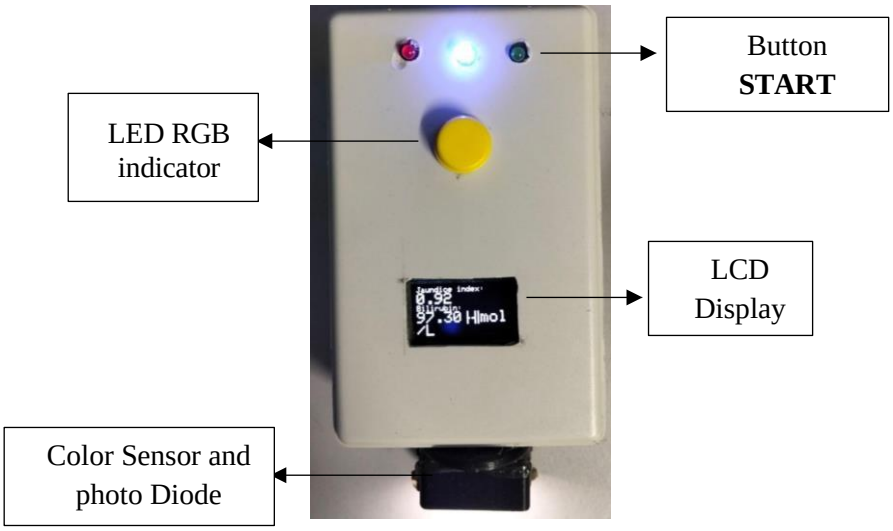

Figure 5: Hardware device

4.2 Application Blynk

Based on figure 6 it shows, the app monitors of jaundice condition of a baby using two critical indicators: Jaundice Index and Bilirubin Level. In the first screen, the baby's profile (named "ira") shows an Age of 7 days and a Weight of 0 (which can be updated later). Both Jaundice Index and Bilirubin Level show a high reading of 99.63 that requires attention. Sliders and gauge meters are used by the app for easy visibility.

The second screen shows a SuperChart tracking the Jaundice Index in real-time. The chart shows the trend of jaundice readings over the short term, helping parents or healthcare providers track trends. The "Live" option is selected, and the information updates in real-time. This app allows for early detection and ongoing monitoring of jaundice without invasive blood sampling, helping to provide quicker and safer intervention.

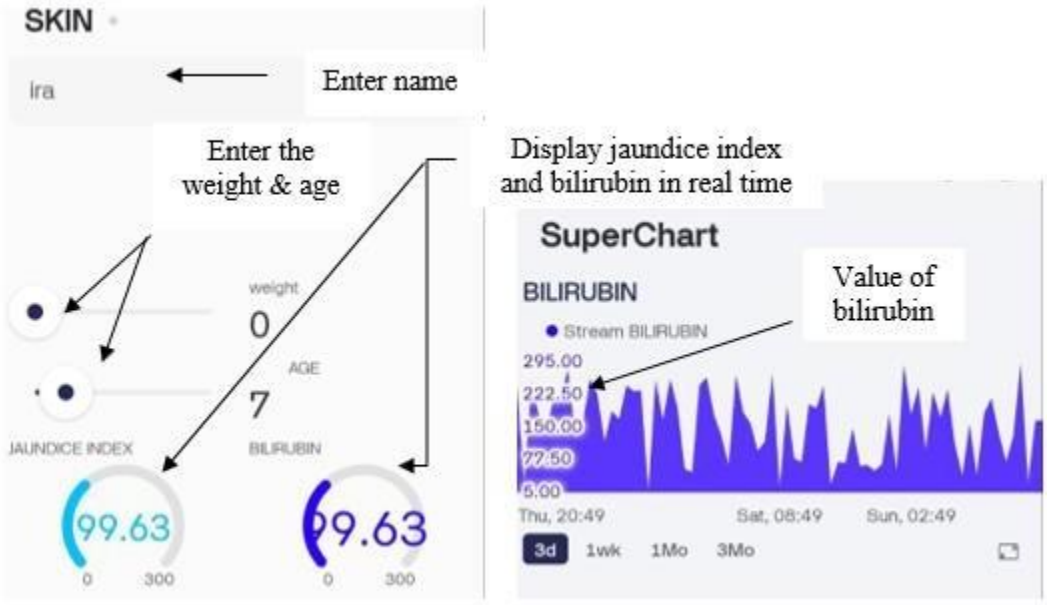

Figure 6: Application in blynks for output

This figure 7 of the app manages automated alerts based on the bilirubin or jaundice index levels. It categorizes the baby's condition into three groups: Low, Moderate, and High. Each category is linked to an automatic action, such as sending a notification or triggering a warning alert.

- Low indicates a safe bilirubin range and minimal concern.
- Moderate signals caution, suggesting the need for closer monitoring.
- High means the bilirubin level is critically elevated and may require urgent medical attention.

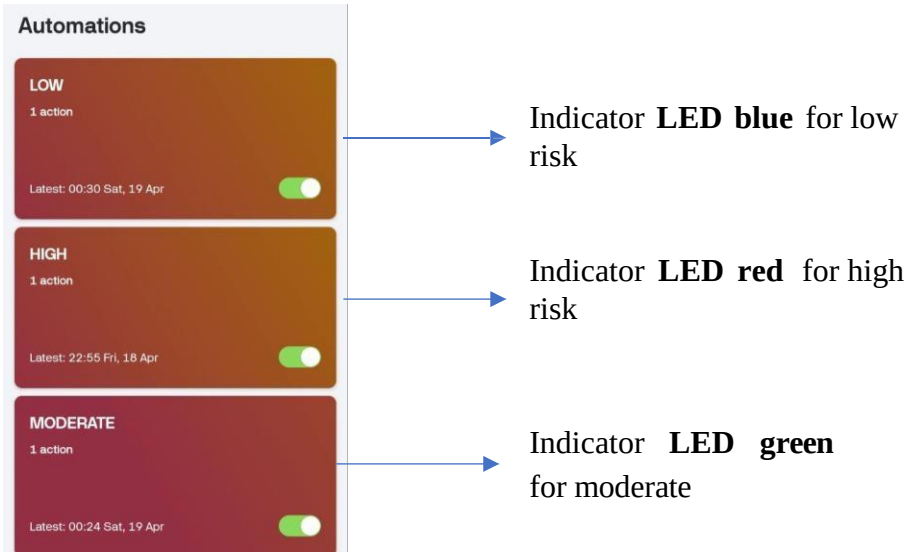

Figure 7: Automation for indicator LED

4.3 Test results using jaundice detectors in babies with jaundice

From table 4.1, the optical sensor system, using a colour sensor and photodiode with an ESP32 module, effectively detected yellowish skin tones. In the first trial, it recorded a LUX value of 145 and RGB values of 165, 213, and 187. Jaundice detector readings (98.81 and 102.69) were close to the hospital's TSB reading of 90, indicating good accuracy. The higher green value corresponds with typical jaundiced skin. Consistent readings across trials confirm the system's reliability and

the ESP32's effectiveness in analysing skin colour using optical signals.

- Weight = 3.36 kg
- Age = 1 week

Table 4.1 Data collection from Jaundice detector testing on newborn forehead.

No. of data by color sensor	No. of attempt	No. of data by Jaundice detector (umoI/L)	Jaundice Index	No. of data by TSB, Yn(umoI/L)	Absolute error, e	Accuracy, A (%)
Lux: 386 Red: 583 Green: 85 Blue: 412	1st	98.81	0.94	90	8.81	91.19
Lux: 240 Red: 354 Green:362 Blue: 295	2nd	102.69	0.98		12.69	87.31

5. CONCLUSION

This work develops an ESP32-based IoT jaundice diagnosis system using photodiodes (for LUX reflectance) and RGB sensors (for yellow pigmentation quantitation) to mimic commercial device operation. Optical signatures - high torso reflectance and outlying G/R ratios - are mapped to clinical bilirubin values by the system, which converts raw sensor data to mg/dL using clinically validated regression models. While real-time signal processing removes environmental artefacts, strict device-specific calibration against serum bilirubin tests is still necessary to ensure diagnostic precision. This multisensory scheme shows promise for affordable jaundice screening but needs additional clinical validation for the achievement of medical-grade accuracy.

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Development Of Wifi-Based Wireless Digital Stethoscope With Enhanced Health Monitoring (Wistetho)

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ABSTRACT

Conventional stethoscopes, while essential in medical diagnostics, pose considerable risks during pandemics and in situations requiring reduced physical contact, due to the close proximity needed between healthcare providers and patients. This increases the risk of cross infection and limits safe patient care. To address this issue, this project proposes the development of a WiFi-based Wireless Digital Stethoscope for Contactless Health Monitoring (WiStetho). The system uses a microphone to capture heart sounds, which are then amplified, filtered and digitized by the ESP32 microcontroller. Unlike traditional implementations using Arduino, the ESP32 offers built-in WiFi capabilities and higher processing power, enabling stable and efficient real-time wireless transmission. The processed sound signals are transmitted to a nearby smartphone or computer, where they are visualized using the Blynk platform to assist in diagnosis. A custom algorithm is developed on the ESP32 to process and display the waveform of the captured sounds, improving diagnostic clarity. The performance and usability of this wireless stethoscope will be assessed through comparative evaluation with standards of measurement defined by the International Society for Holter and Noninvasive Electrocardiology (ISHNE), focusing on accuracy and effectiveness. By reducing physical contact and enabling contactless auscultation in the same space, this system supports better infection control and provides a practical solution for clinical use in isolated environments.

Keywords: Wireless Stethoscope, Heart Sound, ESP32 Microcontroller, WiFi-based Wireless Digital Stethoscope, Contactless Monitoring, Microphone

1.0 INTRODUCTION

The WiFi-based Wireless Digital Stethoscope for Contactless Health Monitoring (WiStetho) addresses critical challenges posed by conventional stethoscopes, particularly in the context of minimizing infection risks during healthcare delivery. For over 200 years, stethoscopes have been essential diagnostic tools for auscultating heart and lung sounds; however, their reliance on close physical contact increases the risk of infection transmission, especially during pandemics. This project introduces a WiFi-enabled wireless stethoscope that allows healthcare providers to listen to heart and lung sounds from a distance of up to 10 meters, significantly reducing the need for direct contact. In a stethoscope, a diaphragm is a thin sheet of material that forms a partition. It is used in acoustic systems to get the best sound possible [1]. With over-moulded silicon, the new stethoscope featured a diaphragm member made of glass and extremely hard epoxy resin. The acoustic surround's flexibility made sound collection much simpler.

These issues have been solved with recent technological developments that have produced WiFi-enabled wireless stethoscopes, which combine wireless connectivity and real-time digital audio processing. WiFi-based Wireless Digital Stethoscope for Contactless Health Monitoring (WiStetho) is designed to allow healthcare providers to listen to heart and lung sounds wirelessly

by connecting the stethoscope to devices like smartphones or tablets which has become more and more crucial in the wake of worldwide medical emergencies like the COVID-19 pandemic [2]. Using WiFi, the system transmits high-quality audio signals in real-time, making it easier for doctors to monitor patients even the patient in quarantine room especially when physical consultations are challenging [3].

1.1 Design Innovation

Design project, as shown in Figure 2, is the project hardware for WiStetho. This includes selecting the appropriate components, such as the microcontroller and microphone wireless, to ensure compatibility and functionality with the system's requirements. Microcontroller is chosen based on its processing capabilities, while the Microphone wireless is selected for efficient wireless communication. As shown in Figure 2, the chest-piece of the conventional stethoscope is integrated with ESP32 microcontroller unit and Wireless communication device. Captured signals are processed and transmitted wirelessly to a mobile device with interface application software for recording, listening and visual display of waveforms.

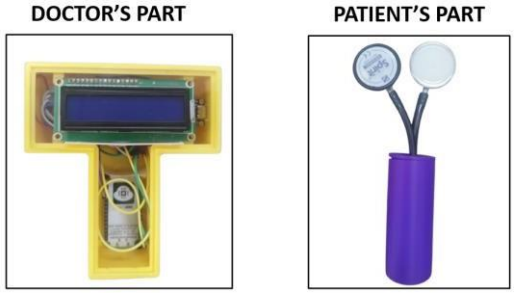

Figure 1: Project hardware of WiStetho

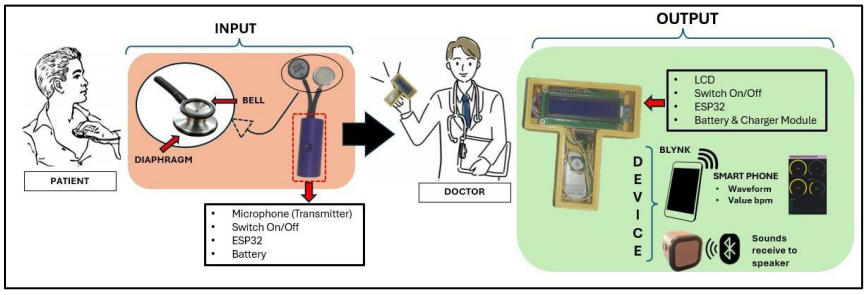

Figure 2: Propose of WiStetho

2.0 METHODOLOGY

The methodology for the system design includes the development of a block diagram to establish the system architecture, outlining key components such as the bell & diaphragm, microphone, amplifier circuits, ESP32 microcontroller and mobile application. After that, the hardware circuits were designed for wireless transmission, noise filtering and amplification. Signal acquisition and signal pre-processing system of electronic stethoscope which is very important part of system is designed. With the help of Proteus software, circuit of signal pre-processing system is simulated, and used to create accurate and useful circuit layouts. Furthermore, the mobile application interface was created to facilitate the seamless receipt, recording, and analysis of data by medical professionals, making sure it is easy-to use and effective platform for managing auscultation data.

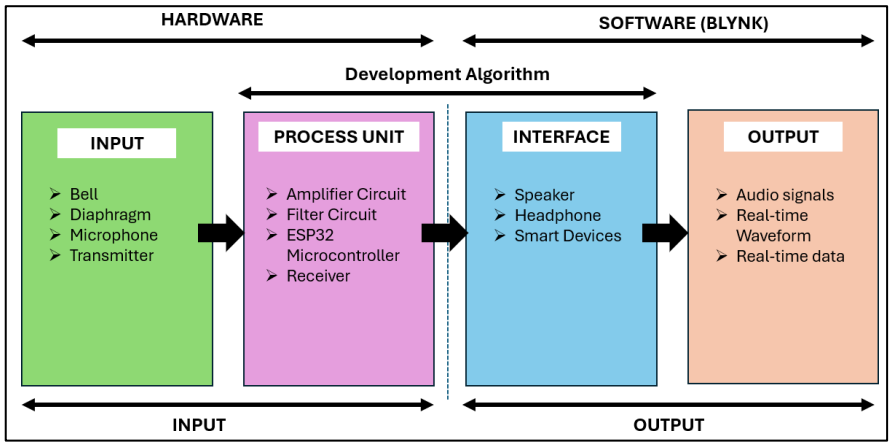

Figure 3: Project Framework of WiStetho

The presented framework, as shown in Figure 3, outlines a comprehensive system designed to integrate hardware and software components for a final year project. The system is structured into three main sections: Hardware, Software (Blynk), and Development Algorithm, each contributing to the functionality and interaction of the project.

2.1 Software Development

2.1.1 Embedded System Programming

The embedded system programming for this project focuses on configuring the ESP32 microcontroller to manage Wireless communication, capture audio input from the microphone, and perform real-time signal processing. The code is written and uploaded using the Arduino IDE, taking advantage of the ESP32's built-in WiFi functionality. The program handles tasks such as reading analogue signals from the microphone wireless, applying filtering and amplification algorithms and transmitting the processed audio data to a nearby mobile application via Hotspot. This ensures that vital sounds like heartbeats and lung sounds are captured clearly and streamed efficiently to the mobile interface for real-time monitoring and analysis.

2.1.2 Mobile App Development

For the mobile application, an Android application can be created using Blynk. Receiving data from the stethoscope, displaying it in real time and enabling functions like recording and storage will all be handled by the app. For healthcare professionals to be able to manage and interpret auscultation data with ease, the app needs to have an intuitive user interface.

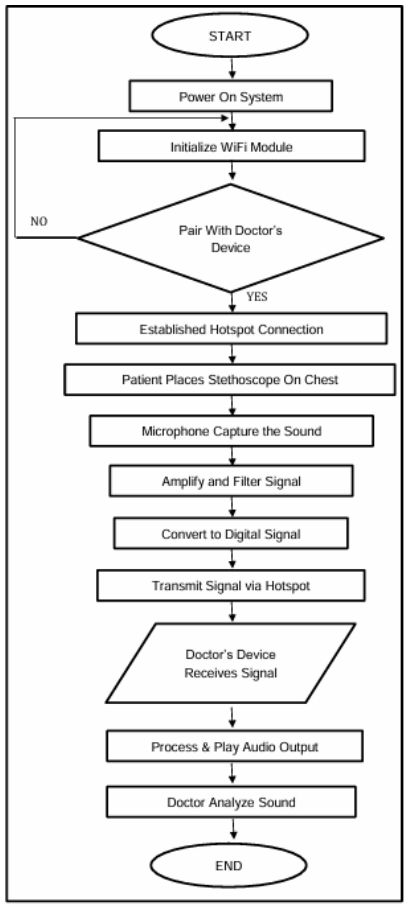

Figure 4: Flowchart of WiStetho

The flowchart as shown in Figure 4 illustrates the signal flow of the wireless stethoscope system. Chest sounds are captured by the bell and diaphragm and converted into electrical signals using the microphone wireless. These signals are then amplified and filtered before being processed by the ESP32 microcontroller. The ESP32 handles digital signal processing and transmits the data wirelessly via Hotspot to a nearby smartphone or devices. The mobile application developed using Blynk, displays the waveform real-time.

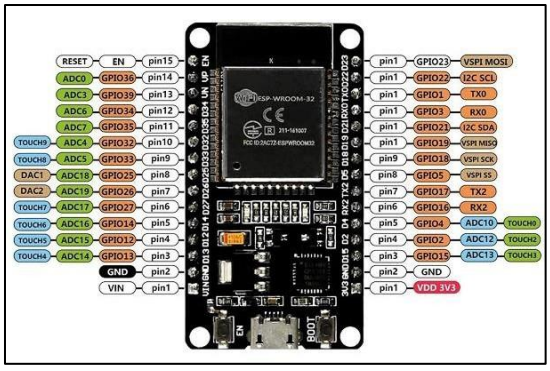

Figure 5: ESP32 Microcontroller [12]

The ESP32 as shown in Figure 5, is a microcontroller chip that offers integrated WiFi and in certain models connectivity for embedded systems that particularly in Internet of Things (IoT) applications. Although the term "ESP32" technically refers to the chip itself, it is commonly used by manufacturers to describe the modules and development boards that incorporate this chip [12].

Figure 6: Microphone Wireless Transmitter and Receiver[13]

3.0 RESULTS AND DISCUSSION

The WiStetho aims to enhance healthcare by enabling real-time transmission of body sounds like heartbeats sounds to connected devices, ensuring immediate analysis for timely diagnosis and treatment. It provides clearer and more accurate body sounds by combining sound amplification and filtering technologies, which is essential for accurate diagnosis even in a noisy environment.

The stethoscope's wireless, non-contact design and user-friendly mobile application increase portability, reduce the risk of infection and enable use in a variety of environments. Future developments, like adding more accurate microphone sensors or advanced analytics, could improve this tool's adaptability for medical diagnostics. Below, as shown in Figure 7 is the accuracy calculation formula from Testbook "Accuracy: Definition, formula, steps, important factors & example," [14].

Accuracy Calculation Formula:

- Percentage Error:

$$\text{Percentage Error} = \frac{Actual\ Value - Measured\ Value}{Actual\ Value} \times 100$$

- Accuracy:

% Accuracy = 100 - % Error

- Average Error:

$$\text{Average Error} = \frac{Total\ Error}{Number\ of\ Tests}$$

- Average Accuracy:

$$\text{Average Accuracy} = \frac{Total\ Accuracy}{Number\ of\ Tests}$$

Figure 7: Equation for Accuracy [14]

3.1 RESULTS AND DISCUSSION

Table 2: Heart Rate Chart for Babies to Adults

AGE (years)	Beats Per Minute (BPM)
New born 0-3 Months Old	100-150
Infants or Babies 3-6 Months	90-120
Infants 6-12 Months	80-120
Children ages 1 - 10	70 – 130
Children age 10 + and Adults	60 – 100
Well-trained Adult Athletes	40 - 60
Adult 20 - 29	99-165
Adult 30 – 39	94-160
Adult 40 – 49	89-151
Adult 50 – 59	84-143
Adult 60 – 69	79-134
Adult 70 and above	75-128

Source: International Society for Holter and Noninvasive Electrocardiology

Heart rate, also known as pulse rate, refers to the number of heartbeats per minute (bpm). It can change depending on the body's need for oxygen or to remove carbon dioxide, such as during exercise, sleep, illness, or after taking certain medications. Since people have a constant blood volume, one way to increase oxygen delivery to an organ is by raising the heart rate, which allows blood to pass through that organ more often. A normal resting heart rate usually falls between 60 and 100 bpm. As shown in Table 4, shows the standard heart rate measurements for different age groups, taking into account factors like physical condition by Standard Measurement of Heart Rate by International Society for Holter and Non-invasive Electro cardiology.

Table 1: Expected Results Measurement using WiStetho

Patient	Parameter	Conventional Stethoscope (CS)	Frequency (CS)	Amplitude (CS)	WiStetho	Frequency (WiStetho)	Amplitude (WiStetho)	Accuracy	Waveform Visualization
Patient 1	Heart Sounds	Normal heart sounds	Normal rate	Normal amplitude	[Value]	[Value]	[Value]	[Value]	[Value]
Patient 2	Heart Sounds	Murmur present	Normal rate	Increase amplitude	[Value]	[Value]	[Value]	[Value]	[Value]
Patient 3	Heart Sounds	Normal heart sounds	Normal rate	Normal amplitude	[Value]	[Value]	[Value]	[Value]	[Value]

This table shows the expected results for a project using a wireless stethoscope called WiStetho, focusing only on heart sounds. It compares what doctors hear using a normal stethoscope with the measurements taken by WiStetho for three patients. For each patient, heart sound characteristics such as frequency and amplitude are recorded and evaluated. The conventional stethoscope provides qualitative descriptions such as normal heart sounds (murmur present) and corresponding acoustic parameters, while WiStetho offers digitally measured values for frequency, amplitude, accuracy, and waveform visualization. This comparison highlights WiStetho's potential in providing more objective and quantifiable diagnostic data, supporting clinical decision-making with enhanced precision. It also helps reduce physical contact between

healthcare providers and patients, lowering the risk of infection transmission.

3.1 CONCLUSION

The development of the WiFi-based Wireless Digital Stethoscope With Enhanced Health Monitoring (WiStetho) using the ESP32 microcontroller presents an effective solution for contactless auscultation in environments that require reduced physical interaction. By integrating the microphone, signal amplification and filtering circuits and WiFi-enabled wireless transmission, the system enables healthcare professionals to monitor heart sounds in real time from a safe distance. The use of the ESP32 microcontroller enhances processing efficiency and wireless communication while the Blynk-based mobile application facilitates intuitive audio playback and waveform visualization. The wireless design reduces the risk of cross-contamination and increases portability, making it highly suitable for use in quarantine settings and high-risk areas. The data measured has been evaluated and compared with the standards of measurement by International Society for Holter and Non-invasive Electro cardiology for accuracy, usability, and effectiveness. This project demonstrates the potential of wireless stethoscope technology to support safe, efficient and practical healthcare delivery in both routine and pandemic conditions.

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Dual Mode Autonomous Wheelchair With Sensor-Based Human Following and Line Navigation

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ABSTRACT

This study presents the implementation of a line-following navigation system in an autonomous wheelchair to improve mobility assistance for individuals with physical disabilities. The objective is to develop an assistive device that can navigate structured indoor environments independently by following designated floor lines, thereby reducing users' reliance on caregivers. The system is built using an Arduino microcontroller, infrared (IR) sensors for line detection, and DC motors controlled via an BTS 7960 43A motor driver to execute precise movements. Initial testing confirms the wheelchair's ability to accurately follow black lines on contrasting surfaces, making smooth turns and correcting path deviations effectively. Although the system is still in the development phase, results indicate its potential to enhance user autonomy and safety in predictable indoor settings. Future enhancements may include obstacle detection, voice control integration, and multimodal navigation features to broaden its usability across diverse environments.

Keywords: Autonomous Wheelchair, Line-following navigation, Mobility assistance, Infrared sensors, and Arduino microcontroller .

1.0 INTRODUCTION

This study aims to address these limitations by developing a dual-mode wheelchair, incorporating two key features: a human-following mode and a line-following mode. The human-following mode utilizes ultrasonic sensors (HC-SR04) to maintain a safe distance (30–80 cm) from caregivers, making it particularly useful in environments like homes or care centres. On the other hand, the line-following mode uses IR sensors (TCRT5000) to follow marked paths, ideal for structured environments such as hospitals or offices, thereby reducing the cognitive load on the user [5][6][7][8].

The system integrates obstacle avoidance and is controlled via an Arduino-based interface, with a user-friendly push-button switch for mode selection. While previous research has demonstrated the potential of dual-mode systems to enhance flexibility and functionality , few prototypes have been tested in real-world healthcare settings, making this study particularly valuable for assessing the practicality and effectiveness of such a system in improving mobility for individuals with physical disabilities[4].

1.1 Line Navigation and Autonomous Guidance

Line navigation provides an essential fall back or complementary mode for autonomous wheelchairs. Traditional methods use sensors and visual inputs to track lines embedded in the environment. IoT-based systems using Arduino and basic sensors have been developed to autonomously navigate hospital corridors by following lines, reducing dependency on caregivers [1]. More sophisticated systems utilize RGB-D (Red-Green-Blue + Depth) data fusion, improving environmental perception and obstacle avoidance by classifying paths, humans, and barriers [2]. Recent studies also explored open-vocabulary object detection in 3D space using RGB-D cameras, enhancing navigation by enabling the wheelchair to recognize a

wide range of objects without prior training [3]. These techniques greatly enhance autonomy, though challenges remain in managing occlusions, variable lighting, and integrating real-time path planning. This study followed a structured engineering approach involving the design, integration, and testing of a single-mode autonomous wheelchair system equipped with line following capability. The main objective was to evaluate whether the wheelchair could accurately and reliably follow predefined black lines across typical indoor environments such as hallways, rooms, and open floor spaces.

2.1 METHODOLOGY

To construct the wheelchair system, a combination of electronic and mechanical components was carefully selected. At the core of the system is an Arduino Uno microcontroller, which processes sensor inputs and controls motor outputs. Infrared (IR) sensors (TCRT5000) were mounted underneath the wheelchair to detect black lines on the floor. These sensors generate analogue signals depending on the surface contrast; black surfaces reduce reflectivity and are detected as the line path. Figure 1(a) shows the front view of the wheelchair , including the sensor housing and overall structure. This visual helps illustrate how the system components are mounted onto the physical frame of the wheelchair.

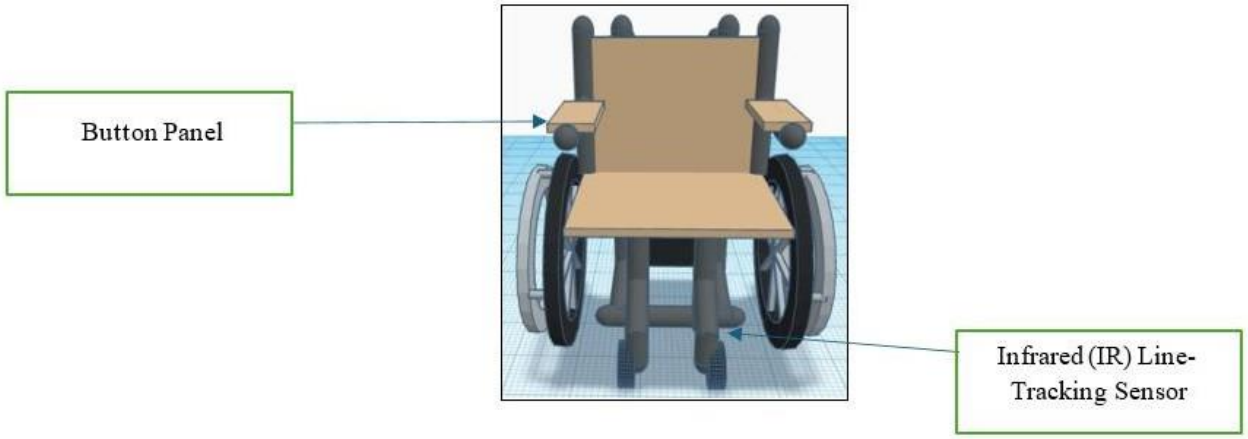

Figure 1(a) : Front View of Wheelchair

Once the system is powered on, a single push button activates the line-following mode. When the user presses the button, the Arduino begins reading input from the IR sensors. Based on these readings, the program decides whether to move straight, turn left, or turn right.

The logic uses conditional thresholding to interpret sensor values and adjust motor directions accordingly. Figure 1(b) provides the bottom view of the , highlighting the placement of the 24 Volts motor at the back and it drive by. These sensors are strategically aligned to ensure optimal detection of the line on the floor.

Figure 1(b) : Back View of Wheelchair

The wheelchair is driven by two 24V high-torque DC motors, which are controlled through an L298N motor driver module. This motor driver receives logic-level signals from the Arduino and delivers sufficient current to drive the motors. The entire system is powered by a 24V lithium-ion battery, which provides consistent power during operation. As Figure 2 presents the block diagram of the system architecture. It shows the interaction between all major components including the Arduino Uno, IR sensors, motor driver, power source, and motors. This diagram serves as an overview of the control flow and hardware configuration.

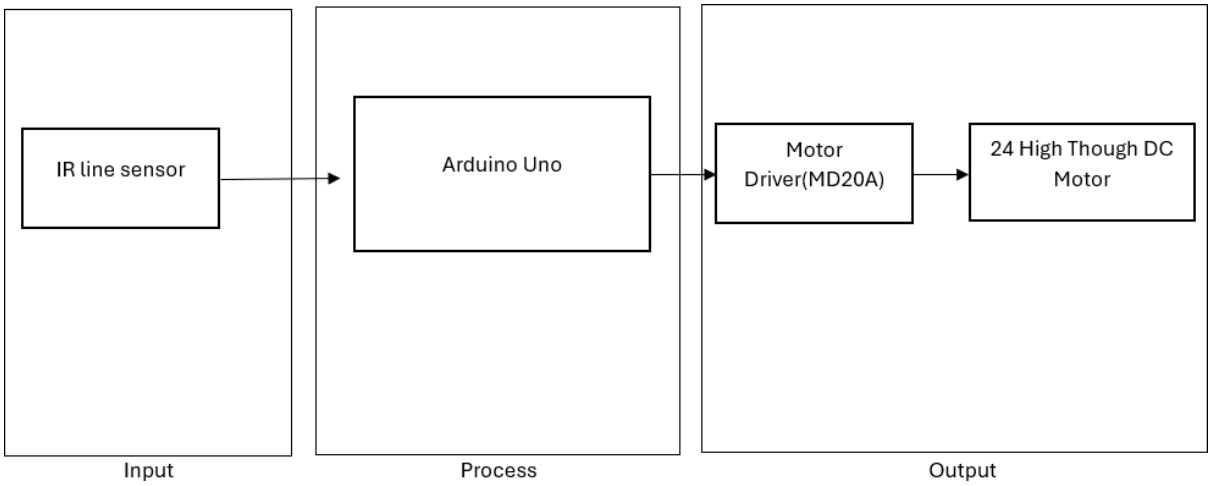

Figure 2 : Block diagram

To test the functionality, a simulation route was prepared using black electrical tape on a white-tiled floor forming various paths including straight lines, turns, and curves. When activated, the wheelchair follows the black line autonomously, correcting its path continuously based on IR sensor feedback. The test environment mimicked the layout of a small room or indoor corridor typically found in homes or clinics.

This method validates the core line-following feature of the autonomous wheelchair, showing that it can operate with minimal user interaction and follow a predetermined path using only onboard sensors and control logic.

2.0 System Development

The development of this autonomous wheelchair focused solely on implementing a line following navigation system using embedded electronics, IR sensing, and motor control. Programming was done using the Arduino Integrated Development Environment (IDE), and all logic was written in C++. The system was designed to activate with a single push button; once pressed, it powers on the IR sensors and begins detecting a black line on the floor. The Arduino Uno then processes this input and sends control signals to the motors to guide the wheelchair along the line.

The core of the system is based on readings from TCRT5000 infrared sensors, which are mounted underneath the wheelchair base to track the contrast between black and white surfaces. These sensors allow the Arduino to determine whether the wheelchair is centred on the path or drifting, and adjustments are made by increasing or decreasing the speed of either motor to steer it back into alignment. The line-following algorithm responds in real-time, ensuring continuous and accurate tracking.

To support this system, the Arduino Uno is connected to an L298N motor driver module, which supplies enough current to run the dual 24V high-torque DC motors attached to the wheelchair's wheels. Power to the entire system is delivered via a 24V lithium-ion battery, ensuring smooth and uninterrupted operation. Figure 3 shows the complete circuit wiring diagram used for the prototype. This diagram outlines the electrical connections between the Arduino Uno, IR sensors, motor driver, DC motors, and push button. It serves as a vital reference for understanding signal flow and troubleshooting during hardware setup.

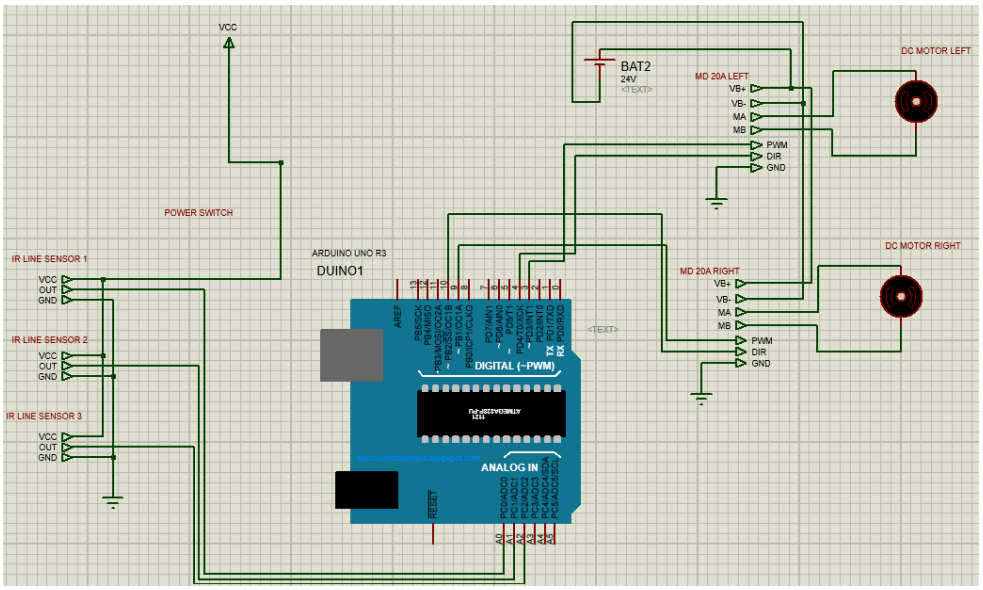

Figure 3 : Circuit Diagram

In preparation for testing, a dedicated track was created on the floor using black electrical tape laid on white tiles. This path includes straight lines, curves, and junctions to simulate typical indoor navigation routes. As illustrated in Figure 4, the layout replicates a simple floor plan similar to what would be found in home or care environments.

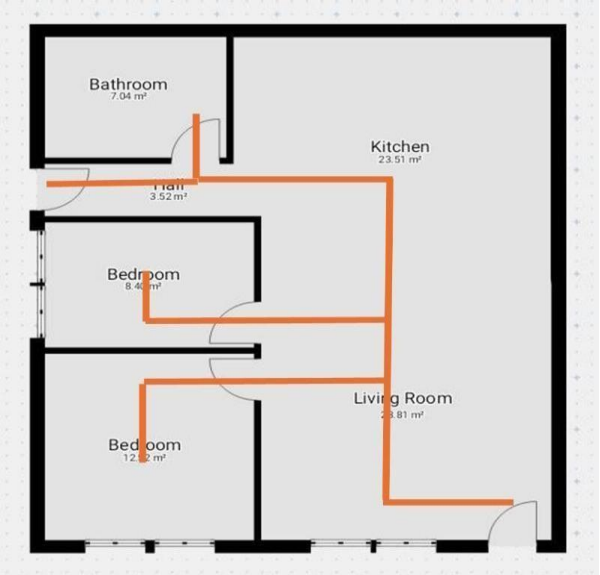

Figure 4 : Line Navigation Plan

The wheelchair was placed at the start of the path, and upon pressing the button, it began moving autonomously along the black line. The IR sensors continuously scanned the line, and the Arduino adjusted motor speeds accordingly to maintain alignment. The system was tested under various lighting conditions and floor surfaces to assess reliability.

3.0 RESULTS AND DISCUSSION

The results from the testing phase demonstrated that the **autonomous line-following wheelchair** prototype was capable of accurately navigating along predefined black-line paths without the need for manual control. All testing was carried out in a controlled indoor environment that simulated typical real-world conditions such as household corridors and small room layouts. The line path was created using black electrical tape on a white-tiled floor to ensure high contrast for the infrared sensors. Once the system was activated through a push button, the IR sensors were able to detect the black line immediately. The Arduino Uno microcontroller processed the sensor readings in real time and controlled the motor speeds to keep the wheelchair aligned with the path. The programmed logic handled decision-making efficiently, allowing the wheelchair to correct its direction whenever it began to deviate from the line.

During testing on straight paths, the wheelchair maintained a stable and centred trajectory, moving forward with consistent speed and minimal correction. When navigating curved or S shaped sections of the route, the system responded effectively by adjusting motor output to steer smoothly along the bends. These smooth transitions demonstrated that the line-following algorithm was properly tuned for path recognition and motor control.

The system also performed reliably in areas with minor surface inconsistencies and under variable lighting conditions. The IR sensors continued to detect the line accurately, which indicates good tolerance to environmental noise and reflection variability.

In repeated trials, the wheelchair was able to complete the entire navigation route with a high level of accuracy. It generally stayed within a 3 to 5 cm range of the centre of the black line and corrected itself quickly if it strayed. This performance confirms that the placement of the sensors and the logic threshold values were appropriate for indoor environments. Overall, the

successful operation of the line-following system supports its potential use in real-world indoor mobility applications. Although this prototype does not yet include obstacle detection, the ability to navigate autonomously along fixed paths represents a significant improvement in ease of use and independence for individuals with mobility impairments. The button-based activation and fully sensor-driven navigation provide a simple yet effective solution, making the system both user friendly and functional for daily use in structured environments.

3.1 RESULT

Reading	IR1 (Left)	IR2 (Center)	IR3 (Right)	Line Position	System Action
1	46.85	0.0	13.18	No line detected	Stop / Realign
2	51.24	0.0	14.15	No line detected	Stop / Realign
3	132.25	0.0	14.64	Line detected on left edge	Turn right
4	304.02	498.74	306.46	All sensors detect line	Go forward
5	325.98	498.74	216.18	Centered with right drift	Go forward
6	337.7	311.83	235.7	Slightly right aligned	Adjust left
7	422.61	395.28	373.32	Balanced detection	Go forward
8	438.71	394.3	337.21	Balanced, slight left lean	Go forward
9	435.78	389.91	293.78	Slight right drift	Adjust left
10	427.98	339.16	147.86	Line moving to left	Turn left
11	415.29	264.5	64.42	Line detected left side only	Turn left
12	393.33	273.28	20.01	Strong left detection only	Turn left
13	204.96	187.39	13.66	Line mostly on left	Turn right / Adjust

Figure 5 : Table of Sensor Value Interpretation and Navigation Response

The table presents the sensor data and corresponding system actions of an autonomous wheelchair designed to follow a black line using three infrared (IR) sensors. These sensors are placed at the left (IR1), centre (IR2), and right (IR3) of the wheelchair's front side. The IR sensors output analogue values where higher readings indicate detection of a darker surface (i.e., the black line), while lower values indicate a lighter surface (such as the floor). The system uses this input to determine the position of the line relative to the wheelchair and makes movement decisions accordingly.

In situations where all three sensors display low readings, as shown in Readings 1 and 2, it indicates that the line is not detected, prompting the system to stop or realign the wheelchair. When only the leftmost sensor (IR1) detects the line, such as in Reading 3, the system interprets this as the line being on the left edge and initiates a right turn to correct its path. Conversely, when only the rightmost sensor (IR3) detects the line (Readings 11 to 13), it suggests the line is on the right side, prompting the wheelchair to turn left. When all sensors detect high values, as in Reading 4, it indicates that the line is directly beneath the wheelchair, and the system continues to move forward.

Some readings show partial alignment, where the wheelchair is slightly drifting to one side. For example, in Readings 5 to 8, all sensors detect the line but with small differences in intensity, suggesting either a slight right or left alignment. In these cases, the system either continues forward or makes minor adjustments. Significant drifts are observed in Readings 9 and 10, where the system detects an uneven distribution of the line across the sensors. This triggers either an adjustment or a corrective turn, depending on the direction of the drift.

Overall, the data demonstrates that the IR sensor array is effective in enabling real-time line detection and movement correction. The system's ability to interpret sensor inputs and translate them into precise motion adjustments ensures that the wheelchair can autonomously and reliably follow the intended path, even in cases of misalignment or sharp turns.

4.0 CONCLUSION

This study successfully developed and tested an autonomous wheelchair system equipped with a line-following navigation feature to support indoor mobility for individuals with physical disabilities. The system, powered by an Arduino Uno and guided by infrared sensors, was designed to follow black lines marked on the floor, providing users with an assistive device that can move independently along predetermined paths without the need for manual control or external guidance.

Through systematic design and testing, the prototype demonstrated consistent performance in detecting and following the line, making smooth turns, and maintaining a stable trajectory in simulated indoor environments. The system also showed immediate responsiveness upon activation, validating the effectiveness of its control logic and sensor configuration. By relying on simple yet reliable hardware and programming, the project achieves its goal of enhancing mobility in structured environments such as homes, clinics, and care facilities. Although obstacle detection and multi-path routing were not included in this version, the successful implementation e following navigation provides a solid foundation for future upgrades. In future work, the system could be improved by integrating additional functionalities such as obstacle avoidance sensors, voice command activation, and mobile app-based control. These enhancements would further increase the wheelchair's usability, safety, and adaptability in more complex and dynamic environments.

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Immersive Virtual Reality (VR) Training for Performance Test of Patient Monitor

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ABSTRACT

This project presents an innovative Virtual Reality (VR) training system that uses the Oculus Quest 2 headset to simulate performance testing of patient monitors with the patient simulator in hospital. Physical performance testing is often seen as less efficient, harder to scale, and more costly compared to modern approaches like cloud-based or virtual performance testing, which allow for on-demand resources, easier test orchestration, and better repeatability. It also reduces safety risks and potential equipment damage during training physically. The objectives of this project are to implement an alternative real-world training platforms using the Oculus Quest 2 virtual reality headset. It also to develop a performance testing simulation that eliminates the medical safety risks. Data from virtual reality simulations will be analyzed to evaluate training effectiveness and user performance. The system is designed using Unity Real Time Development Platform and Blender for 3D modelling. The Virtual Reality (VR) is connected and used in Unity through in Software Development Kits (SDKs) that cover the Oculus Integration and XR Plugin Management. The oculus integration is an SDK provided for Oculus/Meta VR headsets. The XR Plugin Management is Unity's built-in system to manage cross-platform VR features through a modular plugin system. The simulation outputs present the Electrocardiogram (ECG), Heart Rate (HR), Non-Invasive Blood Pressure (NIBP), Peripheral Oxygen Saturation (SpO_2) and temperature readings for displaying waveforms and corresponding value readings. Meanwhile, users will test performance by selecting the appropriate cable and choose the desired reading condition through VR technology.

Keywords: Virtual Reality (VR), Patient Monitors, Patient Simulators, Performance Testing

1.0 INTRODUCTION

Biomedical training is essential for equipping healthcare professionals and biomedical technicians with the skills necessary to operate, maintain, and evaluate medical equipment. This training combines theoretical knowledge and hands-on practice to ensure optimal patient care and safety. As medical technology advances, the demand for specialized training grows, particularly in the operation and maintenance of complex devices such as patient monitors. These devices are critical for tracking vital signs like heart rate, blood pressure, oxygen saturation, and temperature, especially in intensive care settings. Maintaining their accuracy through performance testing is vital for patient safety and effective clinical decision-making[1].

Traditional training methods for performance testing of patient monitors often face significant challenges. The high cost of physical simulators, such as the Fluke ProSim 8, creates financial barriers for educational institutions and organizations[2]. Additionally, improper handling of these devices during training can lead to equipment damage and safety risks[3]. Limited access to such simulators further restricts students and technicians from gaining essential hands-on experience, resulting in gaps in their practical skills and knowledge[4].

1.1 Virtual Reality (VR)

Virtual Reality (VR) refers to a computer-generated environment that immerses users within a simulated world, allowing interaction with 3D objects. By integrating various technologies, such as head-mounted displays (HMDs), head-tracking systems, and sound devices, VR creates a multisensory experience. While VR devices share similar structures, their hardware and software requirements can differ significantly based on application areas. For instance, VR simulators in education emphasize 3D environments and network capabilities, while those for surgical training focus on interaction with virtual anatomical structures.

1.2 Performance Test

Patient simulators are critical tools in healthcare education and training, enabling the safe and effective evaluation of clinical skills and decision-making in controlled environments. The patient simulator is also a tool used to conduct performance tests by simulating real patient conditions to evaluate the effectiveness, accuracy, and safety of medical equipment and clinical procedures in a controlled environment. These simulators, which can range from physical mannequins to advanced digital models, replicate real-world patient responses to various interventions, allowing healthcare professionals to refine their competencies without risking patient safety. The growing integration of artificial intelligence and machine learning into simulator design has further enhanced their utility, providing dynamic, real-time feedback and adaptive scenarios that closely mimic complex clinical conditions.

Performance testing ensures medical devices, like patient monitors, operate accurately and reliably. It involves verifying vital sign measurements (e.g., ECG, NIBP, SpO2, temperature) using patient simulators like the Fluke ProSim 8, which replicates normal and abnormal conditions (e.g., tachycardia, hypoxia). This process identifies device malfunctions, ensuring patient safety and accurate clinical decisions. The VR system simulates these tests, allowing users to practice in a safe, controlled environment without physical equipment risks[5].

Figure 1: Performance Test Using Fluke Prosim 8

In Figure 1, the performance test is shown being conducted hands-on. This step involves real time interaction with the patient monitor and testing equipment to assess their functionality and accuracy before integrating into the VR simulation.

2.0 METHODOLOGY

This project employed immersive Virtual Reality (VR) as a simulation tool to train users in conducting performance tests on patient monitors. The VR system was developed using Unity 3D, integrated with Oculus VR hardware for a fully immersive experience. Participants interacted with virtual patient monitors that replicated real-life scenarios, including error messages, alarm signals, and connection checks based on IEC Standard.

2.1 Block Diagram

The methodology is structured to ensure that the VR system not only replicates real-world scenarios but also provides users with a comprehensive learning experience that bridges the gap between theoretical knowledge and practical application. By leveraging cutting-edge software and hardware tools, the project aims to address the limitations of traditional training methods, such as high costs, limited access to equipment, and safety risks associated with handling delicate medical devices. The process is divided into several key stages, including software and hardware selection, system design, simulation development, and data collection. This structured approach ensures that the final product is not only technologically advanced but also accessible, cost-effective, and capable of enhancing the skills.

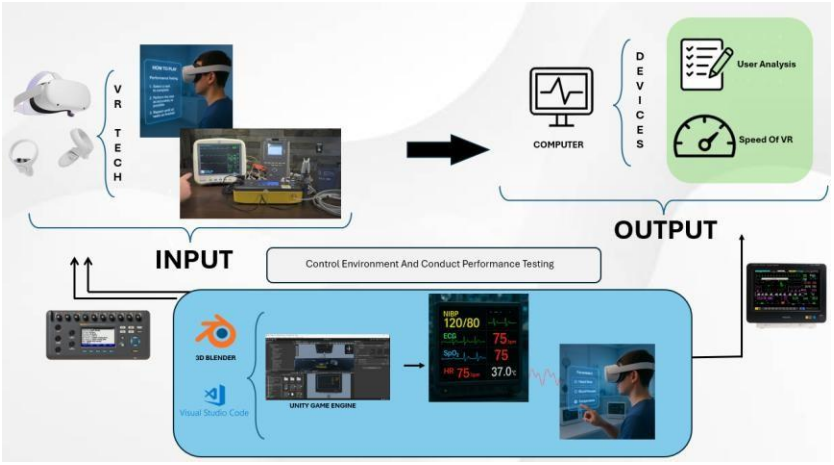

Figure 2: Block Diagram

In Figure 2, the overall architecture of the Virtual Reality (VR)-based patient monitor performance testing system is presented. This diagram provides a high-level representation of the key components involved, including the VR environment, patient monitor, test equipment, and user interaction flow. Each module is interconnected to ensure seamless functionality and accurate simulation of real-world testing scenarios.

2.2 Flowchart

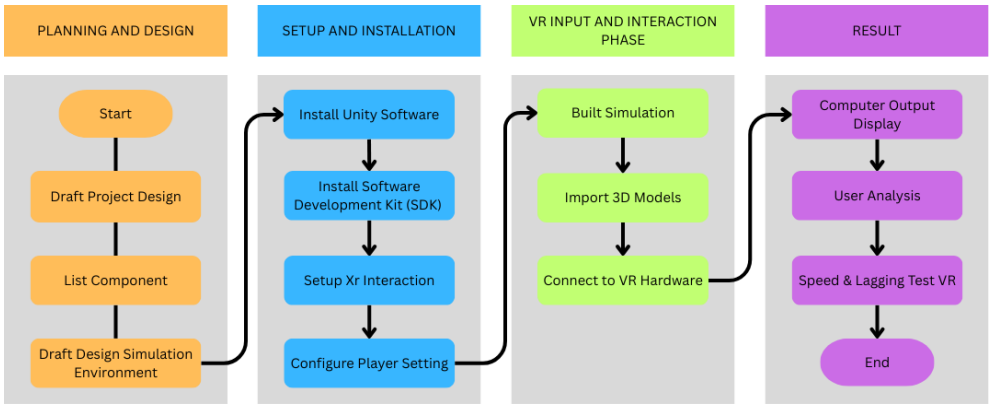

Figure 3: Flow Chart System

Figure 14 shows the development process of the VR training system, which is divided into four phases: Planning and Design, Setup and Installation, VR Input and Interaction, and Result. In the Planning and Design phase, the project design is drafted, required components are listed, and the simulation environment is outlined. The Setup and Installation phase involves installing

and configuring Unity software, SDKs, and XR interaction tools to prepare the VR platform. In the VR Input and Interaction phase, the simulation is built, 3D models are imported, and the system is connected to VR hardware. Finally, the Result phase includes output display, user analysis, and performance testing to complete the development process.

2.3 Virtual Reality (Oculus Quest 2)

The Oculus Quest 2 is a standalone Virtual Reality (VR) headset that redefines accessibility and immersion in VR technology. It integrates powerful computing capabilities with advanced tracking systems, eliminating the need for external sensors or tethered connections to a PC. With its high-resolution display, ergonomic design, and hand-tracking features, the Oculus Quest 2 delivers a highly immersive and interactive experience, making it an ideal choice for applications in gaming, education, and training. In this project, the Oculus Quest 2 is used to create a realistic and safe virtual environment for performance testing of patient monitors, allowing users to practice critical tasks without the risks associated with physical equipment[6].

Figure 4: Oculus Quest 2

In Figure 4, the Oculus Quest 2 Virtual Reality (VR) headset is shown as the primary hardware used in this project. It enables users to engage in an immersive, wireless training environment for conducting performance testing on patient monitors.

2.4 Unity

The VR training system is developed using Unity, a versatile game engine known for its user friendly interface, cross-platform compatibility, and robust tools for creating immersive 3D environments. Unity's physics engine and scripting capabilities enable realistic simulations of medical devices, such as the Philips MX700 patient monitor and Fluke ProSim 8. Its asset store provides pre-built components, reducing development time. Unity's compatibility with VR hardware like the Oculus Quest 2 makes it ideal for creating interactive, realistic training experiences[7].

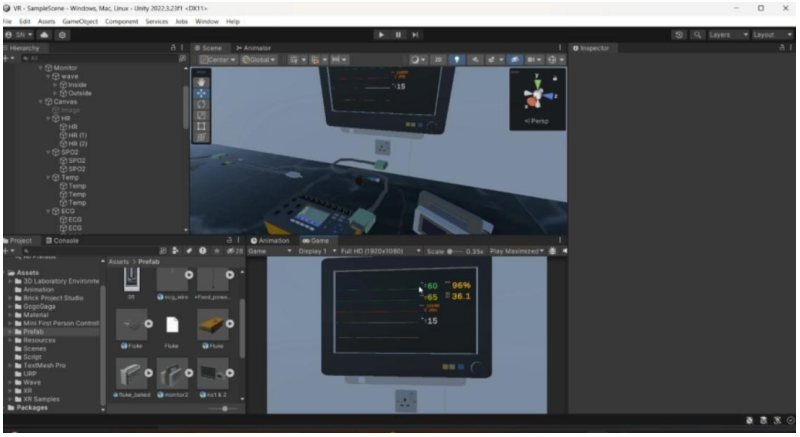

Figure 5: Unity Game Engine

In Figure 5, the Unity development platform is shown being used to design and build the VR based simulation. This environment serves as the core engine where 3D models, interactions, and simulation logic are integrated to create a realistic and interactive training experience for performance testing of patient monitors.

2.5 Blender

Blender is a powerful open-source 3D creation software used for modelling, sculpting, texturing, rigging, animation, and rendering. It is widely used in various industries such as animation, game development, visual effects, and simulation. In the context of healthcare training or virtual reality projects, Blender is especially useful for creating realistic 3D models of medical equipment and environments. Its flexibility, active community, and free licensing make it a popular choice for students, professionals, and researchers working on 3D content creation.

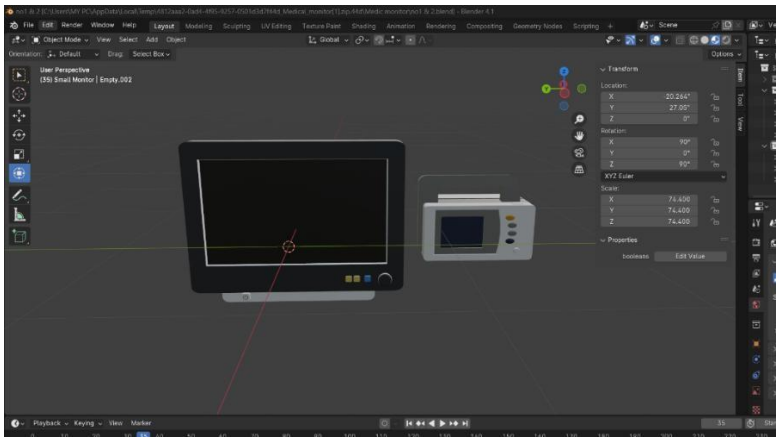

Figure 6: Design 3D drawing using Blender

In Figure 6, the 3D modelling process in Blender is presented, where components such as the patient monitor, patient simulator, and connecting wires are designed. These 3D assets are later imported into Unity to be used in the VR-based simulation, ensuring visual accuracy and realistic interaction within the training environment.

2.6 Google Site

Google Sites is a free, web-based platform developed by Google that allows users to easily create and manage websites without requiring any programming or web design experience. It is widely used for creating project portfolios, collaborative workspaces, educational content, and personal or professional presentations. The platform integrates seamlessly with other Google services like Drive, Docs, and YouTube, making it convenient to embed and organize various types of content. I used Google Sites to create an informative and accessible platform that helps users and external audiences better understand the concept, purpose, and development of the project. By presenting the information in a structured and visually clear format, the site serves as a central hub for showcasing the project's objectives, progress, and outcomes in a way that is easy to navigate and engage with.

3.0 RESULT AND DISCUSSION

This project employed a simulation-based training approach using immersive Virtual Reality (VR) to replicate performance test scenarios for patient monitors. Participants were briefed and introduced to the VR training system before beginning the exercises. Training modules included tasks such as checking alarm functions, ECG lead connections and interpreting

simulated error readings. Timers were used to record task durations, while data processing software collected performance metrics. All data were analyzed to evaluate the effectiveness and accuracy of VR-based training in comparison to traditional methods.

3.1 Design Innovation

This project introduces a design innovation by combining Virtual Reality (VR) technology with realistic 3D simulations of medical devices, such as the Fluke ProSim 8 and Philips MX700 patient monitor. Unlike traditional training methods that rely on physical equipment, this VR based system offers a cost-effective, safe, and repeatable training platform. The integration of Oculus Quest 2 VR headsets and Unity's advanced 3D development tools allows for the creation of highly immersive and interactive environments, where users can practice performance testing procedures without the risk of damaging expensive medical devices. This innovative approach not only bridges the gap between theoretical knowledge and practical application but also promotes sustainability by reducing the dependency on physical simulators and associated resources.

Figure 7: Design Layout Project

Figure 7 shows the virtual lab environment developed for the project, designed to simulate a realistic setting for conducting performance tests on patient monitors. The 3D layout includes workstations with monitors, chairs, shelves, and a participant avatar to represent user interaction within the VR space. This setup provides an immersive and practical training experience that mimics actual biomedical engineering lab conditions.

3.1 User Testing

Users engage in a simulation exercise, performing a performance test on a patient monitor using the immersive virtual reality training system. This system provides an interactive environment where users can test the functionality and accuracy of medical equipment, replicate clinical scenarios, and refine their skills in monitoring and responding to patient conditions. By enabling users to engage with medical equipment and clinical procedures in a simulated setting, the system enhances their learning experience, allowing for effective evaluation of both technical abilities and decision-making skills. This immersive training offers valuable hands-on practice in a controlled environment, contributing to the development of competencies necessary for real-world medical settings.

Figure 8: Project Testing

In Figure 8, an early user testing session is shown. This testing was done to see how users interact with the VR simulation before the final version is launched. It helped identify any issues and allowed improvements to be made based on user feedback, ensuring the system is more effective and user-friendly for future use.

3.2 VrMedSim (Website)

To complement the Virtual Reality (VR) training system and provide users with a more comprehensive learning experience, a dedicated website was developed using Google Sites. This website functions as an interactive guide, offering detailed information about the project's objectives, system components, usage instructions, and safety testing procedures. It is designed to be user-friendly and accessible, allowing users to revisit key concepts, explore visual references, and understand the context of the VR simulation more effectively. Additionally, the website includes interactive elements such as embedded videos, links to related resources, and screenshots of the virtual environment. This integration not only supports independent learning but also enhances the overall usability of the training system. An illustration of the website interface is provided in Figure 9.

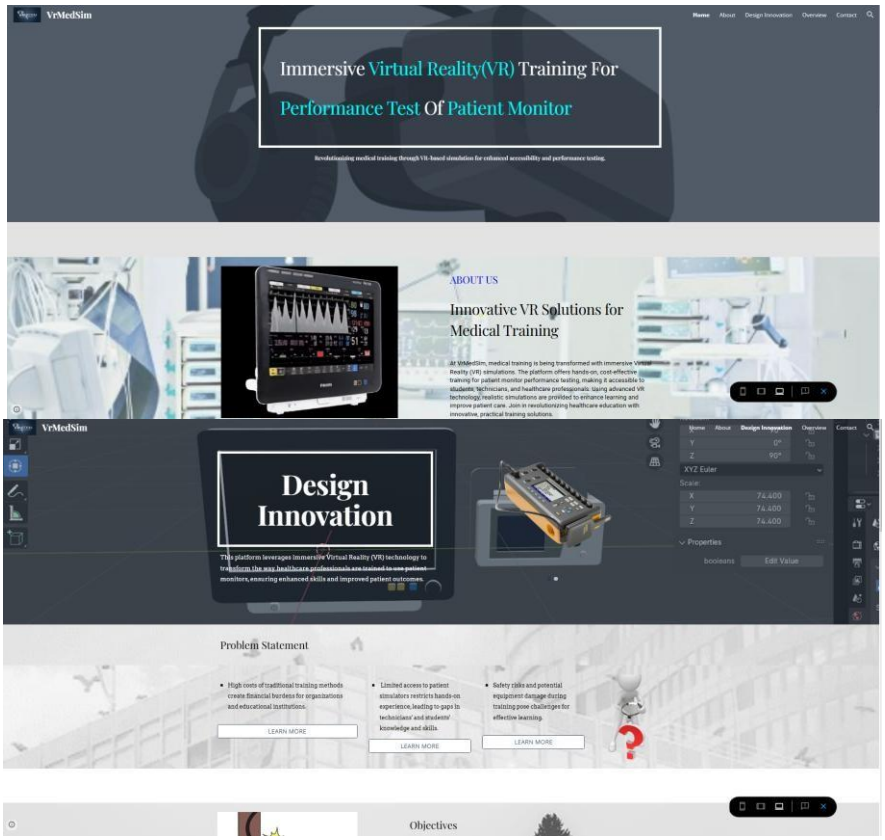

Figure 9: VrMedSim

In Figure 10, the final view of the Google Site created for this project is displayed. This completed version showcases the organized layout, updated project information, and visual elements that make it easy for users to explore and understand the overall project development and outcomes.

3.3 Data Analysis

This data was collected to evaluate the efficiency of the project through a three-day training program utilizing VR-based learning. The patient monitor parameters assessed include ECG, NIBP, SpO_2, temperature, and heart rate. These parameters were tested by simulating patient conditions to observe both value and waveform outputs, enabling verification of the system's accuracy and responsiveness within the immersive training environment.

Table 1 : Task Completion User Type by Time

User Type	**TIME (Minutes)**			
	1st Attempt	2nd Attempt	3rd Attempt	Percentage
Senior Executive, Biomedical	8.25	8.00	7.00	55.56%
Biomedical Engineer (1)	7.50	7.00	6.20	86.67%
Biomedical Engineer (2)	8.40	8.20	7.50	37.50%
Biomedical Engineering Student (1)	7.40	7.00	6.20	85.71%
Biomedical Engineering Student (2)	8.20	8.00	7.40	36.36%

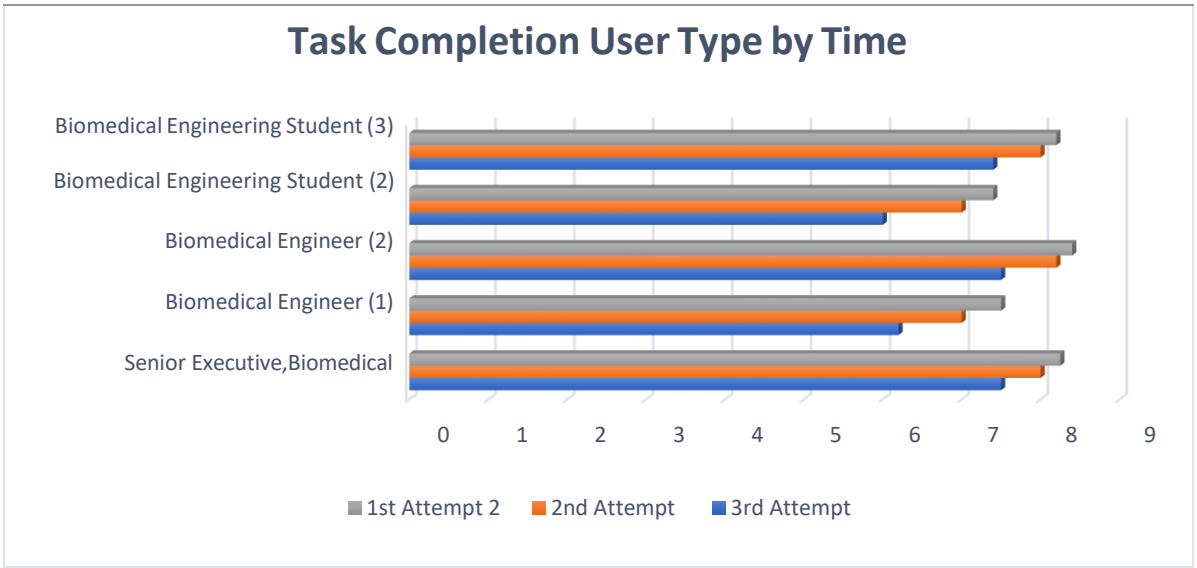

Figure 9: Graph Task Completion

As shown in Table 1 and figure 9, the highest performance improvement was achieved by Biomedical Engineer 1 with an 86.67 percent increase in efficiency, likely due to relevant experience. In contrast, the lowest improvement was recorded by Biomedical Engineering Student 2 at 36.36 percent, possibly due to limited exposure. On average, participants improved by 60.36 percent toward the target time of 6 minutes, showing the effectiveness of VR training in improving task performance through repeated and self-directed practice at lower cost.

4.0 CONCLUSION

The development of immersive Virtual Reality (VR) training for patient monitor performance testing is crucial in advancing practical biomedical education and addressing equipment access limitations. This initiative provides an interactive and cost-effective platform that enhances learning outcomes by simulating real-world testing procedures in a safe virtual environment. The project focuses on replicating performance tests using tools like the Fluke ProSim 8 and Philips MX700, aligned with realistic clinical scenarios to strengthen students' and technicians' technical competencies. Utilizing Oculus Quest 2, Unity, and Blender, the system offers a highly engaging and repeatable training experience, bridging the gap between theoretical knowledge and hands-on practice. As a result, this VR-based training system ensures broader accessibility, reduces reliance on physical resources, and significantly improves understanding of biomedical equipment testing procedures.

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Integrated Movement Support Wheelchair With Gait-Analysis Using IoT

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ABSTRACT

This project presents the development of an Integrated Movement Support Wheelchair with Gait Analysis Using IoT. This project aimed at improving the movement and rehabilitation experience for individuals with lower limb impairments, especially stroke or hemiplegia patients. Traditional wheelchairs often lack the functionality to assist users in performing crucial movements such as transitioning from sitting to standing. Moreover, they do not provide real-time feedback on user movement, which is essential for effective rehabilitation. To overcome these limitations, the proposed wheelchair integrates a mechanical support system driven by a linear actuator to aid sit-to-stand transitions, along with a network of sensors and microcontrollers to monitor gait-related parameters. The data is transmitted wirelessly via the ESP32 module to the Blynk mobile application that enable real-time tracking and user interaction. Safety features such as a secure seatbelt strap and manual control switch are incorporated to ensure user stability during transitions.

Keywords: smart wheelchair, stroke, hemiplegia, sit-to-stand, gait analysis, rehabilitation

1.0 INTRODUCTION

Mobility impairments significantly affect the independence and quality of life for individuals with stroke or hemiplegia. Traditional wheelchairs are widely used as assistive tools. However, they fall short in addressing the transitional needs of users such as standing from a seated position and providing rehabilitation feedback. These limitations hinder the progress of recovery and increase dependency on caregivers (Verma et al., 2024). Additionally, the lack of real-time movement tracking reduces the effectiveness of therapy plans and delays the detection of abnormal gait patterns (Peters et al., 2021).

Recent technological advancements that are particularly on the Internet of Things (IoT) will present promising opportunities to enhance assistive mobility devices. IoT allows for real-time data acquisition and remote monitoring. This making it suitable for rehabilitation applications (Camara Gradim et al., 2020). By embedding sensors and microcontrollers within a smart wheelchair system, users can receive support during sit-to-stand transitions while therapists monitor gait parameters such as step length, cadence, and stance phase remotely (Rodríguez-Fernández et al., 2021).

Gait analysis is a crucial element in physical rehabilitation particularly in post-stroke patients. It enables doctors to evaluate kinematic variables and customize therapeutic interventions to improve walking efficiency. Studies have shown that continuous monitoring of gait dynamics leads to improved recovery outcomes and better patient engagement (Boudarham et al., 2013). The implementation of encoder-based data collection in mobility aids allows accurate tracking of these parameters that offers a measurable and adaptable rehabilitation process (Szerdiová et al., 2014).

This project introduces an Integrated Movement Support Wheelchair embedded with an IoT-enabled gait analysis module and mechanical sit-to-stand support.

It aims to bridge the gap between mobility and rehabilitation by enabling real-time tracking, safety features, and ease of use for users and caregivers.

2.0 METHODOLOGY

The methodology section presents a comprehensive overview of the system development process, including the block diagram illustrating the workflow, a detailed explanation of each hardware component and its function, the overall project design layout, and the schematic diagram representing the electronic circuit configuration essential for the integration of movement support and gait analysis features in the smart wheelchair.

2.1 Block Diagram

The block diagram provides a visual representation of the system's architecture that outline the flow of input, processing, and output components involved in operating the Integrated Movement Support Wheelchair with Gait-Analysis using IoT.

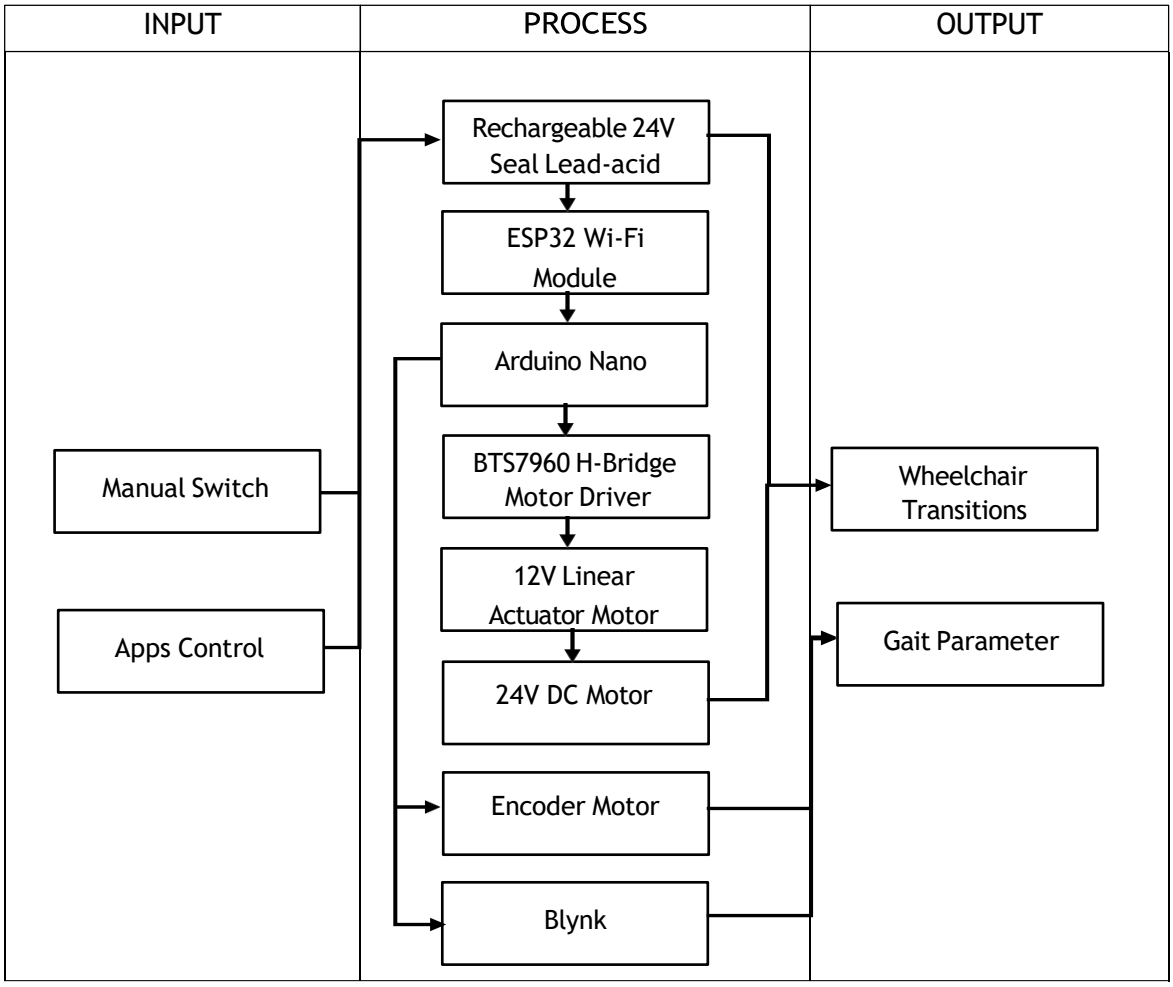

Figure 1: Block Diagram for flow of the project

The block diagram as shown in figure 1 explains how the system components interact to operate the smart wheelchair. Inputs from a manual switch or the Blynk app are sent to the Arduino Nano that controls the motors and actuators through the BTS7960 motor driver. The ESP32 module enables wireless data transmission to the app for real-time monitoring. A 24V battery supplies power and are regulated by a step-down module to protect sensitive components. An encoder motor will collect gait data and will process then displayed through the app. The

process will run while the wheelchair performs sit to-stand transitions and mobility functions based on user commands.

2.2 Materials and Method

This section outlines the essential hardware and software components used in the development of the Integrated Movement Support Wheelchair with Gait Analysis Using IoT. It details the system structure including the block diagram, list of components with their functions, the project design, and the comparison between Integrated Movement Support Wheelchair with Gait-Analysis using IoT with conventional wheelchair.

Table 1: Integrated Movement Support Wheelchair hardware components and it's functions

Components	Functions
Arduino Uno	Acts as the main microcontroller that processes sensor inputs and controls outputs such as motors and actuators. It manages the overall logic of the sit-to-stand transition and movement functions.
ESP32 Wi-Fi Module	Provides wireless connectivity to allow real-time data transmission from the wheelchair to the Blynk mobile app.
BTS7690 H-Bridge Motor Driver	Controls the direction and speed of the DC motors and linear actuator.
300W Step Down Module	Converts the 12V input from the battery to a lower and stable voltage (e.g., 5V or 3.3V) required by sensitive components like the Arduino Uno and ESP32 and protect them from voltage damage.
Rechargeable Seal Lead-Acid Battery 12V 25AH	Serves as the main power supply for the entire system, providing sufficient current to operate motors, actuators, and electronics over extended periods.
High Torque 24V DC Motor	Drives the rear wheels of the wheelchair, enabling forward and reverse movement. Its high torque is essential for carrying the weight of the user and overcoming resistance during motion.
12V Linear Actuator	Facilitates the sit-to-stand and stand-to-sit movement by lifting or lowering the seat platform smoothly. It mimics the natural rising motion to support the user during transitions.
Encoder Motor	Measures wheel rotation and movement data, such as speed and distance. This information is used for basic gait analysis and to monitor the wheelchair's motion behaviour.
Switch	Provides manual control for activating or deactivating the system. It ensures the user can control essential functions even without a mobile connection.
Push Button	Acts as a trigger input for specific actions, such as initiating the sit-to-stand mechanism or stopping movement instantly for safety or convenience.

2.3 Project Design

The Integrated Movement Support Wheelchair with Gait Analysis Using IoT is designed with a focus on functionality, user safety, and compatibility with standard user environments such as clinics, rehabilitation centres, and home settings. The overall dimensions of the prototype are estimated to fall within a typical wheelchair frame size that are approximately 1000 mm (length) × 700 mm (width) × 1000 mm (height), allowing it to navigate standard doorways and indoor paths. The estimated weight of the full system is 30 kg including the mechanical frame, motors, battery, sensors, and control electronics. While this weight is slightly above that of a standard manual wheelchair, it remains within acceptable limits for powered mobility devices.

2.3.1 Sitting Posture

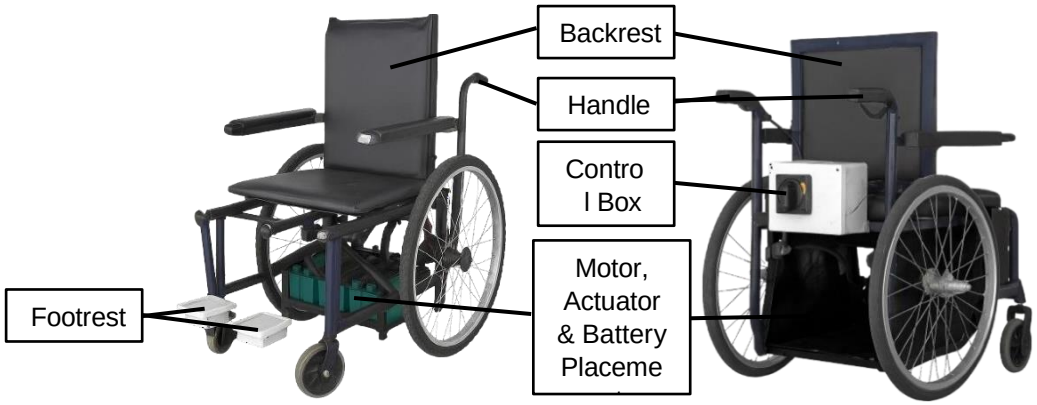

Figure 2: Front and rear design for sitting posture of the product

2.3.2 Standing Posture

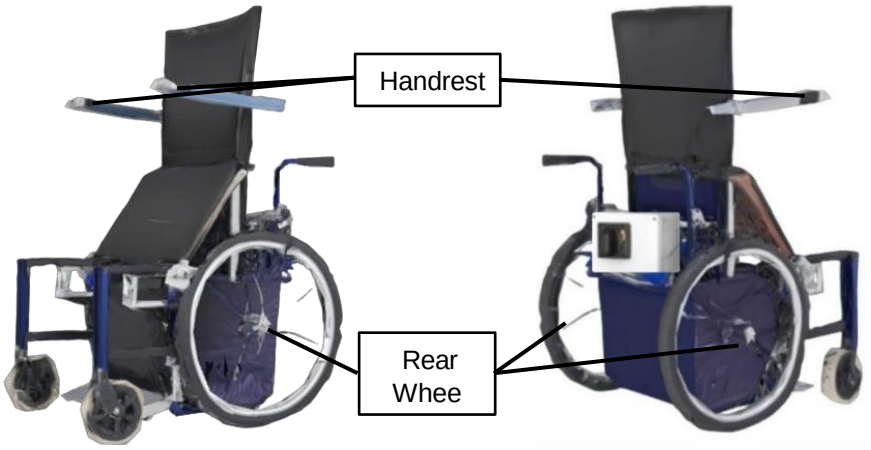

Figure 3: Front and rear design for standing posture of the product

The structure of the wheelchair utilizes a steel alloy or reinforced aluminium frame. Steel offers higher weight capacity and long-term durability, while aluminium provides corrosion resistance and is generally more lightweight which will benefits motor efficiency. The seat and backrest are padded with high-density foam and vinyl upholstery for user comfort during prolonged usage.

Additionally, the system allows for remote monitoring by caretakers or therapists by integrating IoT via ESP32 and real-time tracking via the Blynk mobile app. This feature is particularly important in-home rehabilitation situations for post-stroke patients. (Tuet al., 2020). This digital extension represents a leap forward from standard designs that align with current trends in intelligent and connected healthcare devices.

Compared to conventional wheelchairs, this design integrates advanced mechanical and electronic systems that significantly enhance both mobility and rehabilitation. Standard manual wheelchairs typically lack dynamic transition support and real-time data capabilities. According to (Shiraishi et al., 2019), assistive wheelchairs equipped with powered support systems for sit-to-stand movements significantly reduce the physical strain on users and caregivers. Furthermore, (Rodríguez-Fernández et al., 2021) emphasize the importance of continuous gait monitoring, stating that wearables and sensor-integrated devices improve therapeutic outcomes through personalized feedback. These features are absent in conventional wheelchairs, which are limited to basic locomotion support (Verma et al., 2024).

Table 2: Comparison between Integrated Movement Support Wheelchair with conventional wheelchair

Criteria	Integrated Movement Support Wheelchair	Conventional Wheelchair
Mobility Control	Motorized and automated via embedded system (ESP32/Arduino)	Manually operated (push-rim) or joystick-based (basic electric models)
Gait Analysis	Includes gait data acquisition using encoders/sensors	No gait analysis capability
User Monitoring	Real-time tracking of posture, speed, and position via IoT	No data monitoring or analytics
Remote Access	Remote data logging and control via Wi-Fi integration	Lacks remote capabilities
Safety Features	Attached seatbelt strap will ensure patients safety	Minimal; typically includes mechanical brakes only
Power Supply	Multi-voltage system (24V motors, 9V), optimized power management	Manual or single battery source for basic electric chairs

2.4 Schematic Diagram

To implement an embedded control system using ESP32 and Arduino Uno for coordinated operation of motors, sensors, and IoT communication, a detailed schematic diagram was developed. This circuit-level representation, as shown in Figure 4, demonstrates how various modules including ESP32 Wi-Fi units, motor drivers, actuators, and sensors are interconnected. Each ESP32 handles a specific segment of control logic or data transmission, while the Arduino Uno centrally processes feedback from the encoder and SIM module for motion tracking and communication. The integration ensures precise control of motor movement, gait data acquisition, and remote interaction through the Blynk application.

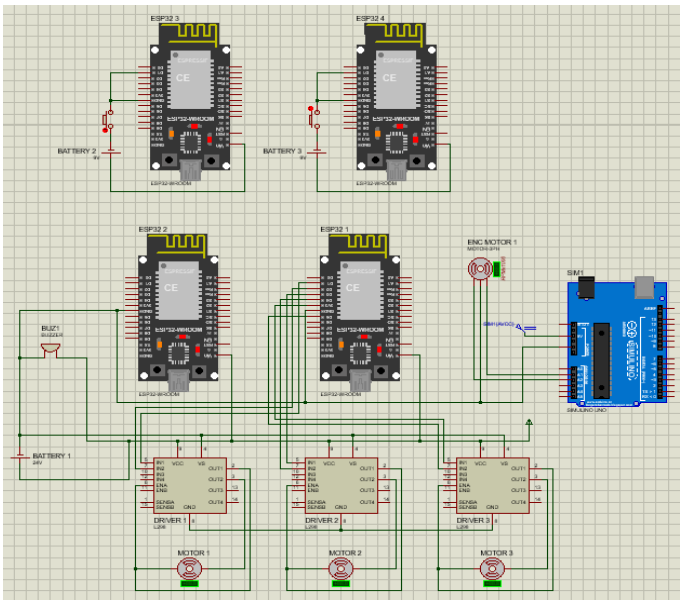

Figure 4: Schematic Diagram of the project

To validate the control logic and voltage behaviour of each component, the entire circuit was simulated using Proteus Design application. Proteus was selected due to its ability to combine microcontroller simulation with accurate electrical behaviour, especially for systems using real-time embedded hardware such as ESP32 and Arduino. Its graphical interface allows easy testing of GPIO logic, motor actuation, and feedback components before physical implementation. Moreover, the software supports virtual monitoring of sensor outputs and power distribution that enable early identification of design issues and saving time during hardware prototyping.

Table 3: Results for the circuit simulation

Component	Observed Output	Expected Behaviour	Analysis
ESP32 (1–4)	3.3V	Operating voltage is 3.3V	Normal operation – all ESP32 units are active and properly powered.
Arduino Uno (SIM1)	5V	Requires 5V to operate	Normal – MCU for control/communication functioning properly.
Motor Drivers (1–3)	3.3V	Typically accept logic levels of 3.3–5V	Acceptable – logic side is powered, assuming motor side is powered via battery.
DC Motors (1–3)	24V & rotating	Requires higher voltage (12–24V) for operation	Motors are functioning and rotating – indicates proper load and control signal.

Encoder Motor (1)	5V & rotating	Typically uses 5V and provides position feedback	Operating correctly – indicates position feedback is available for gait analysis.
Buzzer (BUZ1)	3.3V & buzzing	3.3V sufficient for piezo buzzer	Alert system active and functioning.
Battery (1 - 24V)	24V	Used for high-load components like motors	Stable power supply for motors.
Battery (2 & 3 - 9V)	9V each	Likely powering Arduino or other peripherals	Proper supply levels for backup or dedicated circuits.

To validate the circuit design and ensure the system logic was functioning correctly, the proposed control system was simulated using Proteus Design Suite. Proteus was chosen for its robust ability to simulate both hardware behaviour and firmware execution in a virtual environment. This makes it especially useful for embedded system projects involving microcontrollers such as Arduino Uno and ESP32. Through simulation, we could verify GPIO logic, sensor-actuator response, and motor driver integration before proceeding with physical assembly.

The Proteus Virtual System Modelling (VSM) environment supports co-simulation of microcontroller-based systems, allowing embedded code to interact with simulated real world components. This eliminates early-stage prototyping errors and minimizes development costs (Ćika & Grundler, 2010). In educational and project-based contexts, Proteus also bridges theoretical learning and practical implementation, especially when combined with development platforms like Arduino IDE (Dan et al., 2015).

Furthermore, Proteus enables comprehensive debugging and testing of sensor feedback, actuator motion, and IoT communication routines. This makes it suitable for evaluating the coordination of multiple ESP32 modules, motor drivers, and encoder feedback under a simulated power supply system. The tool's reliability in handling microcontroller circuits makes it an ideal choice for simulating smart wheelchair systems such as ours (Memonova & Botirov, 2020).

2.5 Software

The development of the Integrated Movement Support Wheelchair with Gait-Analysis using IoT relies on two primary software tools which are the Blynk Application and the Arduino Integrated Development Environment (IDE). These platforms are essential in ensuring the system's embedded control logic and real-time communication operate effectively for both the user and caregiver.

Figure 5: Logo of Blynk Application

The Blynk Application is an IoT-based mobile interface that enables remote control and monitoring of physical hardware devices via smartphones. In this project, Blynk was utilized to design a customized user interface that facilitates real-time interaction with the smart wheelchair system. Through the Blynk app, users can activate the sit-to-stand function, control wheelchair direction, and view gait-related data such as step count, cadence, and distance walked. The app receives and sends data wirelessly through the ESP32 module using Wi-Fi, allowing seamless communication between the hardware system and the mobile device. This real-time feedback and control capability significantly enhance the functionality of the wheelchair, especially in rehabilitation scenarios where constant monitoring and assistance are critical. The application provides caregivers and patients with an intuitive and reliable method to engage with the system remotely, supporting rehabilitation from home or in clinical environments (Tu et al., 2020).

Figure 6: Logo of Arduino IDE

Meanwhile, the Arduino Integrated Development Environment (IDE) serves as the programming platform for the microcontrollers used in this system, including the Arduino Uno and ESP32. The Arduino IDE supports C/C++-based programming, enabling developers to write, compile, and upload code to the hardware. It is through this software that the control logic for movement transitions, data collection from the encoder motor, and communication routines for IoT features are developed and implemented. The Arduino IDE also allows for serial monitoring and real-time debugging, which simplifies the integration of sensors, actuators, and motor drivers. By providing a stable and adaptable programming environment, the Arduino IDE ensures that the embedded system performs accurately and reliably under various operational conditions (Dan et al., 2015).

Together, these software tools form the core of the system's smart functionalities. The Blynk application enhances user experience and control, while the Arduino IDE enables the development and refinement of core microcontroller logic. Their integration ensures that the wheelchair system is both interactive and adaptive, aligning with modern standards in assistive rehabilitation technologies.

3.0 RESULTS AND ANALYSIS

The evaluation of the Integrated Movement Support Wheelchair with Gait-Analysis using IoT involved a series of experiments designed to assess its efficiency, real-time data transmission, and gait-monitoring capabilities. The system was tested on two categories of users which is one with normal mobility and another being a stroke patient with lower limb impairments. The results were collected and analyzed through three experimental procedures, and are discussed in terms of performance, accuracy, and reliability.

The first evaluation focused on the system's responsiveness during sit-to-stand and stand-to-sit transitions without having subjects on it, which was measured using the Blynk IoT application to detect time delays in real-time monitoring. Across three trials, the average time recorded for

the sit-to-stand function was 26.21 seconds, while the stand-to-sit transition averaged 25.27 seconds. The close range of timings across all repetitions demonstrated the stability and reliability of the actuator system. Additionally, the synchronization between the user interface and hardware was observed to be highly responsive, confirming that the IoT-based feedback loop between the ESP32 module and the Blynk app functions with minimal latency. This supports efficient user interaction and ensures safety during transitions, particularly for patients requiring constant monitoring.

Table 4: Data for IoT Monitoring Time Lag

Trial	First Trial	Second Trial	Third Trial	Average/s
sit-to-stand	26.5s	26.55s	25.59s	26.21
stand-to-sit	25.21s	25.3s	25.29s	25.27

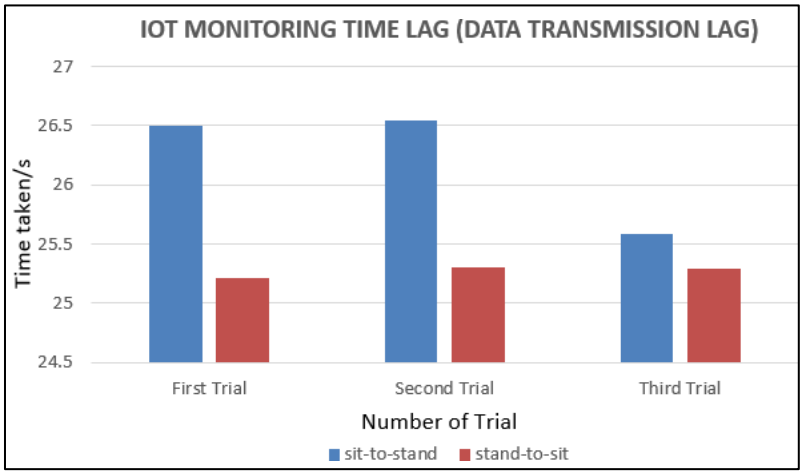

Figure 7: Chart for IoT Monitoring Time Lag

The second experimental dataset analyzed the time taken for sit-to-stand transitions by two subjects: a stroke patient and a normal person. The stroke patient required an average of 30.31 seconds, while the normal subject averaged 22.41 seconds. This difference highlights the expected variation in physical ability, with the smart wheelchair system providing effective support for both users. While the stroke patient took longer due to muscle weakness and coordination challenges, the system offered consistent and smooth transitions, validating its utility in therapeutic rehabilitation and caregiver-assisted environments. The data confirms that the integrated motor and actuator system performs reliably under varied physiological conditions (Shiraishi et al., 2019).

Table 5: Data for Time-Taken for Sit-to-Stand Transition with Subjects

Time / Taken Subject	1	2	3	Average/s
Stroke Patient	31.01	29.89	30.03	30.31
Normal Person	23.64	21.98	21.6	22.41

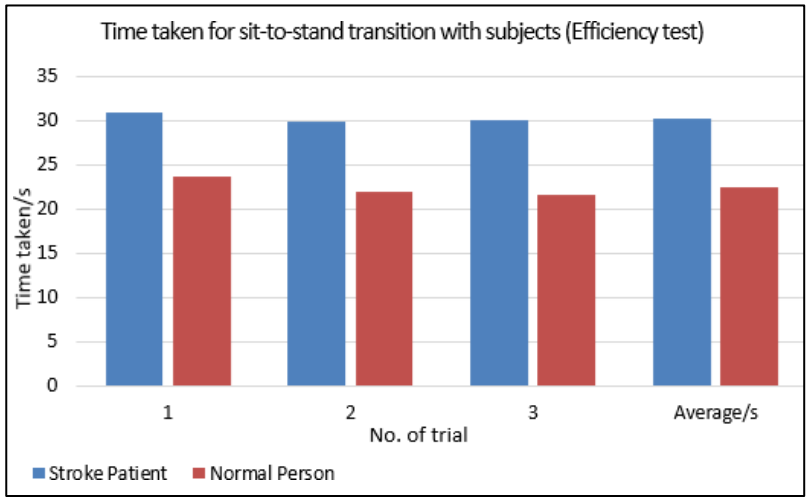

Figure 8: Chart for Time-Taken for Sit-to-Stand Transition with Subjects

The third experiment involved a 5-meter forward walking test to assess gait parameters, including step count, cadence, and overall movement performance. The normal subject completed the walk in 9.59 seconds, taking 15 steps with a cadence of 1.56 steps per second. The stroke patient, in contrast, required 15.2 seconds and took 21 steps with a cadence of 1.38 steps per second. These results indicate that although the stroke patient required more steps and time, the system successfully captured detailed kinematic data, reflecting their slower and more effortful gait pattern. The data collected by the encoder motor was accurately visualized through the mobile app, demonstrating the effectiveness of the system's gait-monitoring capabilities. This function is particularly beneficial in clinical rehabilitation, where continuous feedback can guide therapy adjustments and track recovery progression (Boudarham et al., 2013; Rodríguez Fernández et al., 2021).

Table 6: Data for 5-Meter Forward Movement (Kinematic Data for Gait-Analysis)

Subject	Timer/s	Right Feet Step	Left Feet Step	Total Step	Cadence (steps/s)	Distance/ m
Stroke Patient	15.2	11	10	21	1.38	5
Normal Person	9.59	7	8	15	1.56	5

Equation 1: Cadence

$$Cadence = \frac{Total\ Steps}{Minutes}$$

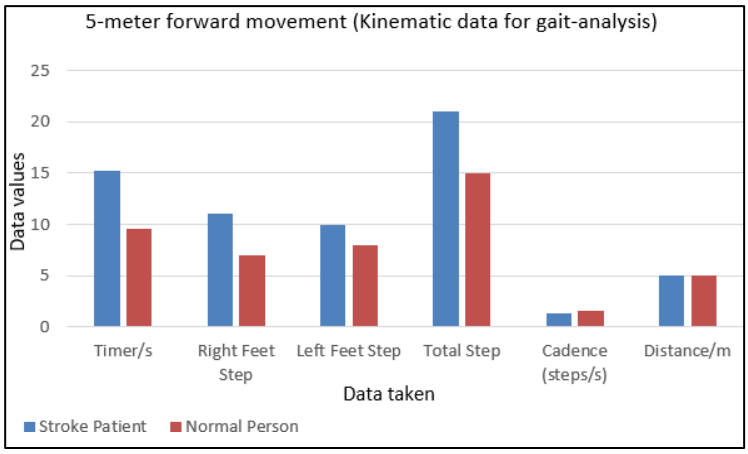

Figure 9: Chart for 5-Meter Forward Movement (Kinematic Data for Gait-Analysis)

Overall, the experiments confirm that the Integrated Movement Support Wheelchair performs reliably in real-world scenarios involving both healthy and mobility-impaired users. Its ability to assist with movement transitions, provide real-time monitoring, and conduct basic gait analysis makes it a valuable rehabilitation tool. The data-driven insights gathered through this system allow for personalized therapy planning, while its smart automation reduces the burden on caregivers and promotes user independence.

4.0 CONCLUSION

The development of the Integrated Movement Support Wheelchair with Gait-Analysis using IoT has achieved its intended objectives by offering an effective assistive solution for individuals with lower limb impairments, particularly stroke patients. This project successfully integrates a mechanical sit-to-stand support system with real-time gait monitoring features, all coordinated through an IoT-based control and feedback interface.

Through experimental testing, the system demonstrated consistent and reliable performance during key movement tasks such as sit-to-stand transitions and short distance walking. The use of encoder sensors enabled accurate gait parameter collection, including step count and cadence, which are essential for monitoring rehabilitation progress. The real-time data transmission via the Blynk application allowed for seamless interaction between the user and the system, supporting remote monitoring and control. The results affirm the system's capability to enhance mobility, ensure user safety, and contribute positively to the rehabilitation process. Compared to conventional wheelchairs, this smart wheelchair provides additional functional advantages such as posture adjustment, gait tracking, and wireless monitoring. As a result, it not only supports physical movement but also facilitates a more structured and measurable rehabilitation routine.

In conclusion, the project presents a practical, user-centred, and affordable technological solution that can be implemented in both clinical and home care settings. With further refinement and long-term evaluation, this system has the potential to become a valuable tool in modern rehabilitation strategies.

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Object Detection With Audio Assistance System For The Blind

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ABSTRACT

This study presents the development of a real-time object detection system designed to enhance environmental awareness and navigation for visually impaired individuals. Visually impaired individuals face significant challenges in identifying and avoiding obstacles in their immediate surroundings, limiting their independence and mobility in daily life. The system utilizes a Raspberry Pi 4, an AI camera, earphones, and employs the OpenCV library for object detection and Google Text-to-Speech (TTS) for audible feedback. Detected objects are converted into real-time verbal notifications, enabling users to perceive their surroundings more effectively. The project evaluates the effectiveness, accuracy, and usability of the system in improving situational awareness and daily mobility for visually impaired users. Tests demonstrate that the system reliably identifies common indoor and outdoor objects, promoting greater independence and reduced reliance on human assistance.

Keywords: Vision Problems, Object Recognition, Audio Information, Raspberry Pi 4, Open CV.

1.0 INTRODUCTION

Blind and visually impaired people (BVIP) face a range of practical difficulties when undertaking outdoor journeys as pedestrians. Everyday tasks such as crossing streets or avoiding obstacles can be hazardous, often requiring assistance from others or reliance on traditional aids like canes or guide dogs [1]. Visually impaired people have problems identifying or realizing what is happening around them [2]. They often walk with their arms stretched forward to anticipate the collision in front [3]. Hence, visually impaired people need to use aids for them to walk and detect obstacles ahead. Additionally, difficulty in identifying or interpreting their surroundings increases the risk of accidents and diminishes confidence, particularly in unfamiliar or complex areas [4]. These challenges often result in a reliance on assistance from others, reducing independence and autonomy. Object Detection With Audio Assistance System For The Blind addresses this need with a cutting-edge technology solution designed to improve safety and independence Leveraging the power of AI and computer vision, the system uses an integrated camera paired with a computer-driven object detection algorithm [5]. This combination allows the device to assess the environment and analyze nearby items, including trucks, motorcycles and vehicles in real time [6]. This system was developed using a Raspberry Pi 4 equipped with an AI camera to detect objects in the user's environment in real time. The use of computer vision technology through the OpenCV library allows the system to identify basic objects such as humans, chairs, tables and other obstacles commonly found in indoor environments. In addition, this system also includes an audio output mechanism that uses Google Text-to-Speech (TTS) technology. Information related to the identified objects will be converted to voice form and delivered to the user through a pair of earphones. The technology improves user navigation by providing real-time audio feedback for both moving and stationary obstacles in the surroundings. It detects dynamic hazards, such as approaching vehicles and provides timely alerts that help users make safer decisions.

2.0 LITERATURE REVIEW

a) Limitations Blind People

Individuals with blindness experience a significant shift in how they interact with the world, often requiring adaptive skills, support systems and assistive technologies to navigate their surroundings safely and independently [2]. Visual impairment or blindness causes direct and indirect effects on the bearer. Direct impact, in the form of limitations that occur in individuals due to vision abnormalities such as not being able/difficulty in seeing, and difficulty/limited in movement. Indirect impact, is in the form of the blind person's own reaction to his vision abnormalities such as: minder, feeling powerless, despair, and others [7]. Table 1 shows the type of visual acuity of partially blind people [8]:

Table 1 Type of visual acuity of partially blind people.

Type	Description
Blurred Vision	Images are out of focus, both near and far (for example due to cataracts or high myopia).
Hazy Vision	Like seeing through fog (common in cloudy corneas or cataracts).
Distorted Vision	Straight lines look curved (for example in macular degeneration).
Central Vision Loss	Blind spot in the center of vision, but peripheral vision is still present (eg: macular degeneration).

b) Hearing Sensitivity for Blind People

Early-blind individuals have superior hearing abilities compared to sighted individuals is partially true, but it comes with important nuances and limitations. When someone loses their vision early in life, the brain reorganizes itself to compensate which a process called cross modal plasticity. Areas of the brain that would normally process visual information (especially in the occipital lobe) get "recruited" to handle auditory tasks instead [9].

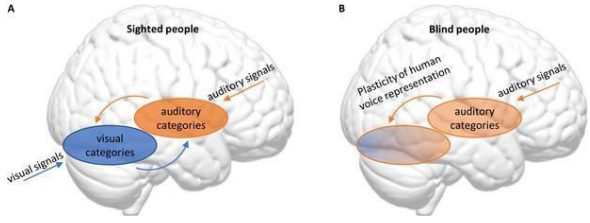

Figure 1 Visual And Auditory Cortices in the Brain[10].

This figure 1 shows how the brain adapts to blindness by reorganizing how it processes visual and auditory information. In sighted people, visual and auditory signals are processed separately in specific brain regions, which also communicate with each other. In blind individuals, the visual cortex (VOTC) takes on a new role by helping to categorize sounds, like human voices, due to the lack of visual input. The typical auditory areas become less specialized in this task. This shift highlights the brain's plasticity, showing that regions typically dedicated to vision can adapt to support auditory functions in the absence of sight [10].

C) Raspberry Pi

The system utilizes machine learning algorithms to analyse video feeds in real-time, identifying specific objects or people and distinguishing between normal and suspicious activities. By training on a large dataset of images and scenarios, the machine learning model improves its accuracy and adaptability, allowing the security camera to effectively recognize patterns and make decisions without constant human oversight [11]. Raspberry Pi used was Raspberry Pi 4 Modul B and Raspberry Pi AI camera.

The Raspberry Pi is an affordable, compact computer about the size of a credit card, powered by an ARM processor. The latest model, Raspberry Pi 4 as in Figure 2, features a 1.2GHz quad-core processor, 1GB of RAM, built-in Wi-Fi, Bluetooth, 40 GPIO pins, four USB ports, an Ethernet port, HDMI, audio jack, and camera/display connectors. It supports various Linux based operating systems, with the primary OS being Raspbian, a Debian-based system tailored for Raspberry Pi [17]. The Raspberry Pi 4, a powerful single-board computer, has gained significant traction in developing AI-driven applications due to its enhanced processing 13 capabilities and affordability. Combined with AI cameras, the Raspberry Pi 4 opens up new possibilities for real-time data processing, object detection, and visual recognition, especially in projects that require compact, low-cost, and portable solutions.

Figure 2 Raspberry Pi 4 Modul B

Figure 3 show about the Raspberry Pi AI Camera is an advanced camera module designed to work with Raspberry Pi devices, offering enhanced image quality and versatility for various applications. Released as an upgrade to the earlier camera modules, this high-quality camera is equipped with improved features that make it suitable for professional [13]. AI cameras, when paired with the Raspberry Pi, are used extensively in applications requiring object detection and tracking, thanks to their ability to capture and process high resolution images. Cameras such as the Raspberry Pi AI Camera, compatible with the Raspberry Pi 4, can capture images and videos in high definition and are compact enough to be integrated into portable systems. Studies show that AI cameras equipped with machine learning algorithms can detect objects, 14 identify motion, and recognize faces or specific features,
making them ideal for security systems, home automation, and assistive technology for visually impaired individuals [14].

Figure 3 Raspberry Pi AI Camera

d) Audio System

The study highlights that audio-based systems are effective in enhancing mobility for blind users, as they rely on sound cues to understand their surroundings, improving both safety and independence in daily activities. This approach is part of a growing field of assistive technology aimed at empowering visually impaired individuals through innovative, user-friendly solutions [15]. By using AI algorithms, these systems translate visual data into sound, providing users with verbal cues or audio signals to help them interpret their surroundings. Research on audio guidance systems, such as the Blind Museum Tourer studied by Meliones and Sampson (2018), shows that audio cues can effectively convey spatial and directional information, making it easier for visually impaired users to navigate complex environments. Voice instructions play an important role in helping visually impaired individuals to navigate their environment more safely and effectively. For example, an AI-based navigation system can instruct users to stop or move in a certain direction when there are obstacles or approaching vehicles [4]. This research demonstrates that auditory feedback can serve as a reliable substitute for visual information, particularly when paired with AI enhanced object recognition systems.

3.0 METHODOLOGY

a) Project Idea

This concept was inspired by the difficulties that blind people confront when attempting to understand their surroundings. While some people can feel the existence of close objects through physical contact, they are generally unable to recognize those objects or appropriately analyse their surroundings beyond a certain distance. To solve this problem, the project employs an object detection system created specifically to help blind individuals recognize their surroundings more effectively and safely.

The proposed system combines a Raspberry Pi 4 with an AI camera to recognize objects in real time. This combination allows the system to recognize typical objects and deliver instant feedback to the user. Unlike traditional aids like canes, which can only identify physical obstacles, this device visually scans the environment and translates it into audio output. The hardware components are positioned on a chest holder for hands-free operation, allowing users to move freely and comfortably without restriction based on figure 4. By combining portability, real-time processing, and audio instructions, this system aims to enhance the independence and mobility of visually impaired individuals, especially in indoor environments.

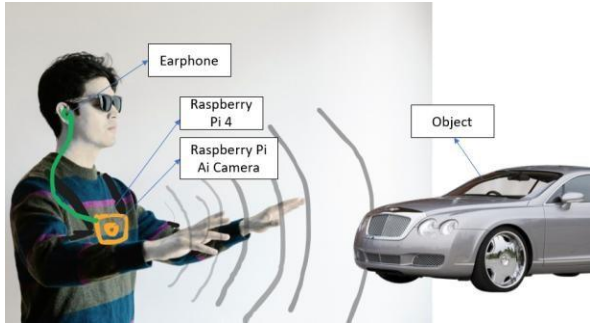

Figure 4 Idea of Product

b) Product Development

Based on figure 5 show the flowchart of product development. This project develops a navigation assistance system for the visually impaired using computer vision technology. The system operates on a Raspberry Pi 4 platform with key components including a Raspberry Pi AI camera,

power bank and earphones. The process begins with the design phase where system specifications are determined. We selected OpenCV for image processing and gTTS for text-to-speech conversion, considering their compatibility with Raspberry Pi. Hardware components were chosen based on performance, cost, and usability factors.

The software development stage involved creating object detection algorithms using OpenCV. We optimized the code for real-time performance on Raspberry Pi. The audio system was developed with gTTS to provide clear information to users. Upon completion, the program was tested to ensure basic functions operated correctly. Initial tests were conducted in controlled environments to verify object detection accuracy and audio output quality. The hardware integration phase connected all physical components. The camera was mounted on the Raspberry Pi, audio system connected, and power bank integrated for mobility. The final product was housed in a suitable casing.

Field testing was conducted in various indoor and outdoor locations. The system was evaluated based on detection accuracy, response time, and usability in real world situations. Performance data was collected and analysed to assess system effectiveness. Results showed the system could help blind users identify surrounding objects with satisfactory accuracy in different environments.

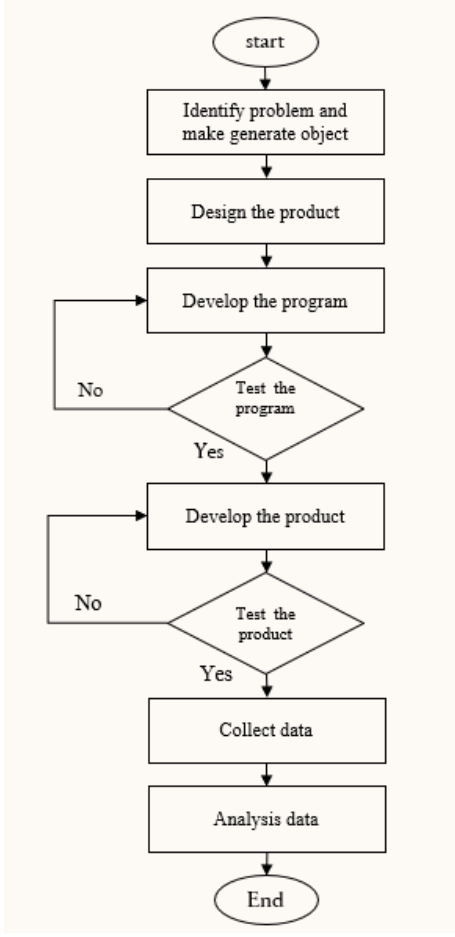

Figure 5 Flow Chart of Product Development

c) Experimental Setup

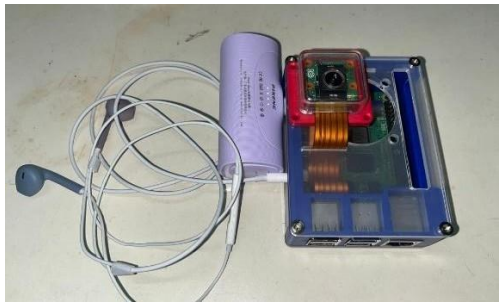

Figure 6 Hardware Setup

Figure 6 shows the hardware setup for this project involves several key components which is a Raspberry Pi 4, a Raspberry Pi AI camera, a pair of earphones, a power bank, and a custom-designed casing with a chest holder. The chest holder is specifically designed to be worn at chest level, ensuring optimal camera positioning for object recognition while also allowing the user to move freely. Its ergonomic design helps distribute the weight evenly, making it comfortable to wear for extended periods without restricting upper body movement shown in Figure 7. These elements work together to form a compact, wearable system that supports the real-time object detection process. The combination of the Raspberry Pi 4 and the AI camera serves as an effective pairing for capturing and processing visual data from the user's surroundings.

The AI camera plays a crucial role in capturing images of nearby objects, acting as the system's "eyes." Meanwhile, the Raspberry Pi 4 functions as the central processing unit (CPU), or the "brain" of the system, handling all computational tasks related to image processing and system control. Audio output is delivered through earphones, which serve as the medium for communicating instructions to the user. These instructions are generated based on object recognition results and are conveyed in real-time, allowing the user to respond to their environment effectively.

In terms of software, figure 8 shows the system utilizes the OpenCV library for object detection and recognition. Once an object is identified, Google Text to-Speech (TTS) technology is used to convert the detection results into spoken words. This enables the user to receive clear and immediate audio feedback, enhancing their situational awareness and navigation capabilities.

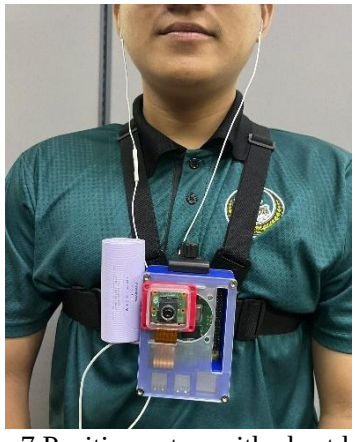

Figure 7 Position setup with chest holder

Figure 8 Object Detection and Recognition

4.0 RESULT

The data collection process for this project was divided into two main components which is accuracy measurement and the determination of minimum and maximum detection distance for each object. Each object was tested 20 times to ensure consistency and reliability of the results. The testing was conducted in both indoor and selected outdoor environments to evaluate the system's performance under different lighting and spatial conditions.

a) Accuracy

The accuracy data, as shown in the figure 9 includes metrics such as mean Average Precision (mAP) and Recall values for various objects like persons, chairs, cars, and bottles. This approach allowed for a comprehensive assessment of the system's object detection capabilities, including how effectively and at what distance it could identify different objects in real world settings. Based on the graph, the highest mAP percentage is 90%, recorded for the bottle, while the lowest is 75% for the chair. In contrast, the highest Recall percentage is 70%, achieved by both the person and car categories. The lowest Recall value is 45%, also recorded for the chair.

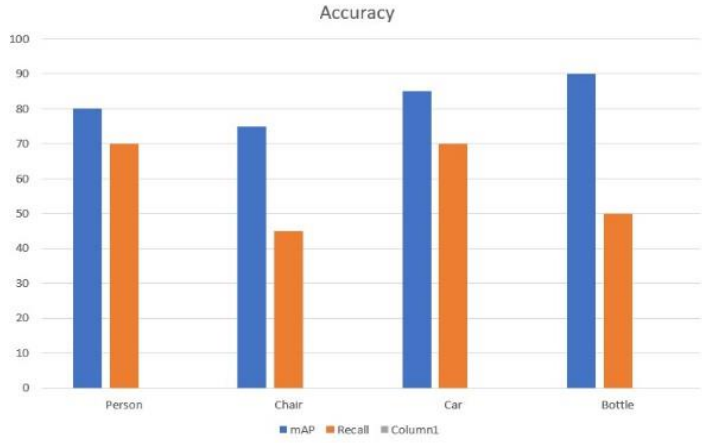

Figure 9 Comparison of Accuracy Across Different Objects

The figure 10 below demonstrates that the object detection system is functioning effectively. The system successfully detects objects in front of the camera and generates an audio output accordingly. For example, in this scenario, the system identified a person with a confidence level of 99.86% and delivered a verbal output stating, "*Saya nampak person dengan keyakinan 99.86 peratus*". This confirms that the integration of object recognition and audio feedback is working accurately and in real time, providing clear information to the user.

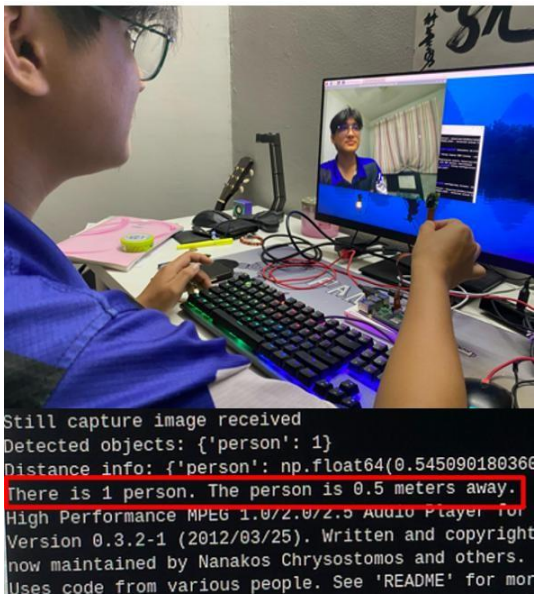

Figure 10 Output Object Detection

b) Distance

Table 2 Minimum And Maximum Detection Distances

Object	Min distance (meters)	Max distance (meters)
Person	0.7	7
Bottle	0.3	3
Car	3	15
Chair	1.5	7

Table 2 above outlines the minimum and maximum detection distances for several objects, providing insight into the range capabilities of the object detection system. For instance, the system can detect a person from a minimum distance of 0.7 meters and up to 7 meters, which is effective for identifying individuals in both indoor and outdoor environments. This allows the system to give users sufficient warning when someone is approaching or nearby. The detection range for smaller items, such as bottles, is between 0.3 and 3 meters, which shows the need for the system to be closer in order to correctly identify less noticeable objects. When detecting larger objects such as a car, the system performs exceptionally well, with a detection range extending from 3 meters to 15 meters. This is especially beneficial for outdoor scenarios, such as crossing streets or navigating parking areas, where early awareness of vehicles is critical for user safety. Lastly, the system can detect a chair at distances between 1.5 meters and 7 meters, making it suitable for indoor navigation where furniture is a common obstacle. These varying detection ranges demonstrate the system's ability to adapt to different object sizes and contexts, ultimately supporting visually impaired users in navigating their surroundings more confidently and safely.

Table 3 Comparison Between the Actual Distance of An Object and the Distance Measured by the System

Actual (meter	System measure (meter)
0.5	0.4
0.7	0.5
1	0.7
2	1

Based on table 3 show in navigation assistance systems for the visually impaired, accurate distance measurement is a critical factor determining the effectiveness and safety of the device. This study evaluates system performance by comparing actual object distances with system-measured distances, particularly for objects in the 'person' category. Experimental data reveals several measurement variations. In the context of sensor-assisted navigation system evaluation, distance measurement accuracy serves as a fundamental metric for assessing system reliability. Experimental data demonstrates the system's tendency to report shorter distances than actual measurements for 'person' category objects.

5. CONCLUSION

The development of the Object Detection with Audio Assistance System for the Blind demonstrates a practical and impactful application of modern technology to enhance the quality of life for visually impaired individuals. By integrating a Raspberry Pi 4, AI camera, and Google Text-to-Speech (TTS) into a wearable device, the system successfully provides real time object detection and audio feedback. This enables users to receive timely verbal alerts about their surroundings, significantly improving their mobility, independence, and situational awareness.

Testing results indicate that the system performs reliably across a range of indoor and outdoor environments, accurately identifying common objects such as people, cars, bottles, and chairs. The detection distances and accuracy metrics confirm the system’s ability to support users in navigating complex spaces safely. Moreover, the ergonomic design and hands-free operation contribute to user comfort and practicality.

In conclusion, the project achieves its objective of creating an affordable, portable, and effective assistive tool for the blind. It represents a promising step forward in accessible technology, with potential for further improvements and broader real-world application through future enhancements such as obstacle avoidance, GPS integration, and advanced AI capabilities.

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Powered Quick Respond QR Code In Pharmaceutical Dispenser Using An Embedded System With AI Assistant

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ABSTRACT

The project focuses on designing an AI-powered pharmaceutical dispenser integrated with Quick Response (QR) code technology and an embedded system. The dispenser addresses critical challenges in healthcare, such as medication non-adherence, limited pharmacy access, and human errors in manual dispensing. By incorporating artificial intelligence (AI), the system analyzes health data, recommends medications, and ensures accurate dosage dispensing. The QR code functionality allows seamless user interactions, prescription validation, and personalized medication management. Utilizing components such as the Esp 32, infrared sensors, and chat bot technology, the system improves accessibility, safety, and efficiency in medication delivery. This innovative approach enhances patient care, minimizes healthcare inefficiencies, and sets a foundation for scalable solutions in automated healthcare delivery systems. The project demonstrates significant potential to revolutionize healthcare accessibility and medication adherence through intelligent automation.

Keywords: AI-powered pharmaceutical dispenser, QR code technology, Embedded system, Esp 32, HealthCare accessibility

1.0 INTRODUCTION

Embedded systems are essential in the development of modern automated vending machines, particularly in the healthcare sector. These systems consist of microcontrollers specifically designed to perform dedicated tasks in real time. In the context of medicine dispensing, embedded systems enable precise control over machine operations, such as user input detection, motor control, sensor monitoring, and secure medication storage (DB, Kumar, et al, 2021).

The use of embedded system-based vending machines in medical applications allows medications to be dispensed automatically and without human supervision. This helps reduce the workload on healthcare personnel and eliminates common human errors such as incorrect dosing or misinterpreted prescriptions (Meghla et al, 2022). Microcontrollers like Raspberry Pi or ESP32 are commonly used to control mechanical components such as servo motors and temperature sensors for medicine storage (Meghla et al, 2022).

Despite the advantages of modern medication vending machines, a number of drawbacks continue to reduce their usefulness in actual healthcare settings. Many of the systems in use today lack personalization features and have low intelligence. They frequently have set dispensing schedules that make it difficult to accommodate patient-specific requirements like age, comorbidities, or allergies. Furthermore, these devices usually lack real-time symptom analysis and drug verification, which raises the possibility of over-the-counter (OTC) abuse and inappropriate medicine use (Zubair et al , 2024). Because they lack strong safety features like prescription validation, patient identification, or appropriate temperature regulation for delicate medications, some versions are also susceptible to mechanical failure or unauthorized access (Ahtiainen et al , 2020). These weaknesses highlight the need for an AI-enhanced, user-centric

system that can address the evolving demands of modern healthcare while maintaining operational security and efficiency.

These systems also support user-friendly interfaces such as LCD screens and physical buttons, making them suitable for use by the general public, including elderly users or those with limited technical knowledge. With Internet of Things (IoT) connectivity, information such as medicine inventory, machine status, and usage records can be transmitted in real time to a central database for remote monitoring (CH. Patil et al, 2022). Furthermore, these vending machines have great potential in rural areas or during emergencies like pandemics, where access to pharmacies is limited. They offer the public a way to obtain essential medications like paracetamol or ORS without needing to visit a healthcare facility. This aligns with the global vision of inclusive, affordable, and equitable digital healthcare systems (Bhosale et al, 2021).

The integration of QR codes for secure medication management in healthcare settings. QR codes can enhance patient privacy, control access to medical records, and improve infusion confirmation processes (Yan & Lu, 2018). An automated drug dispenser using QR codes has been proposed to streamline prescription fulfilment, displaying crucial medication information and facilitating secure payments (Shanthini et al., 2024). A visual cryptography-based QR code system for medication administration aims to prevent errors by encoding patient information and prescriptions into multiple QR code transparencies, ensuring correct medication distribution (Ti et al., 2020). These innovations demonstrate the potential of QR code technology to significantly improve medication management security, patient safety, and overall healthcare efficiency.

The integration of Quick Response (QR) code technology adds another layer of security and usability to the system. QR codes act as digital keys that contain user identification and prescription data stored in encrypted format. By scanning the QR code, users can securely access their medical records and initiate the dispensing process with minimal effort and maximum speed (Bhosale et al, 2021).The combination of embedded systems and QR code technology supports a dispensing process that is efficient, secure, and user-centric. It also facilitates the monitoring of treatment compliance (medication adherence), which is crucial for long-term healthcare outcomes, particularly for patients managing chronic conditions. Such systems are suitable for use in clinics, universities, workplaces, and community settings (M.Sadikin et al, 2016).

The integration of an AI-powered smart assistant, the system becomes more dynamic and interactive. The AI module can identify symptoms based on user input, recommend suitable over-the-counter medications, and guide users through safe dosage instructions via a chatbot interface. This not only enhances medication safety but also empowers patients to practice safe self-medication in a smarter, more efficient manner (Chang et al, 2022) (Hiremath et al, 2022).

This project focuses on the design and development of dispenser that utilizes an embedded system integrated with QR code technology. The goal is to create a system that provides intelligent, real-time dispensing of medications while maintaining a user-friendly interface for patients. The prototype is tailored to dispense four common over-the-counter (OTC) medications paracetamol, Oral Rehydration Salts (ORS), Ponstan, and Chlorpheniramine targeting frequent ailments such as fever, headache, stomach ache, and flu. By combining AI-driven diagnosis with QR-based authentication, this system not only enhances accessibility but also supports self-medication practices in a safe and regulated manner (Aldeer et al, 2018).

2.0 METHODHOLOGY

The methodology for this project describes the systematic approach and tools used to design, develop, and assess the AI-powered pharmaceutical dispenser integrated with QR code technology. The integration of AI and QR code technology in pharmaceutical dispensing systems to enhance efficiency and reduce human errors. These systems utilize AI algorithms for assistant, computer vision for QR code scanning, and embedded devices for hardware management (K. Joshitha et al., 2024; Shanthini E et al., 2024). Human-cantered AI design is crucial for successful implementation, with pharmacists emphasizing the need for simplicity, interpretability, and clear visualization of AI confidence levels (Yifan Zheng et al., 2023). AI applications in healthcare extend beyond dispensing, encompassing drug discovery, treatment development, and patient management (Ajay I. Patel et al., 2022). These advancements aim to improve patient safety, streamline healthcare processes, and enhance overall medication management in the pharmaceutical industry.

The process of this project is divided into five main phases, including the design of system requirements for both hardware and software using tools like Tinkercad and Proteus. The integration and assembly of embedded components such as ESP32/Raspberry Pi, servo motors, and a QR scanner to create a functional prototype for dispensing Paracetamol, ORS, Ponstan, and Chlorpheniramine. The development of software modules comprising an AI-based chatbot for symptom analysis, QR code-based authentication, and a user-friendly interface via Telegram bot and Chat GPT the testing and validation phase to ensure functional accuracy, reliability, and user satisfaction based on existing benchmarking studies; and finally, the integration of QR and AI modules into a microcontroller platform applying machine learning techniques for intelligent medication mapping and real-time data logging.

The methodology involves utilizing a variety of technological resources such as A oriented machine learning approaches for data processing, embedded devices for hardware management, and software interaction with end-users. By taking this methodical approach, the project shall be accomplishing its objectives of reducing pharmaceutical errors, encouraging improved accessibility, and enhancing healthcare automation in general.

2.1 BLOCK DIAGRAM

The block diagram is a graphical representation that shows how important functions inside the designed system flow is called a block diagram. It provides an organized and easily comprehensible representation of the relationship between the input, process, and output of the complete system. The purpose of this project's block diagram is to illustrate the roles and interactions of the key elements that went into creating the AI-powered pharmaceutical vending machine that utilizes QR code technology. Each block stands for a crucial element, such as the output mechanism that regulates the motor for medicine delivery, processing through the ESP32 microcontroller and sensors, and the user input system (chatbot and QR code). Throughout the system development process, this method makes it easier to arrange the program flow and hardware layout efficiently.

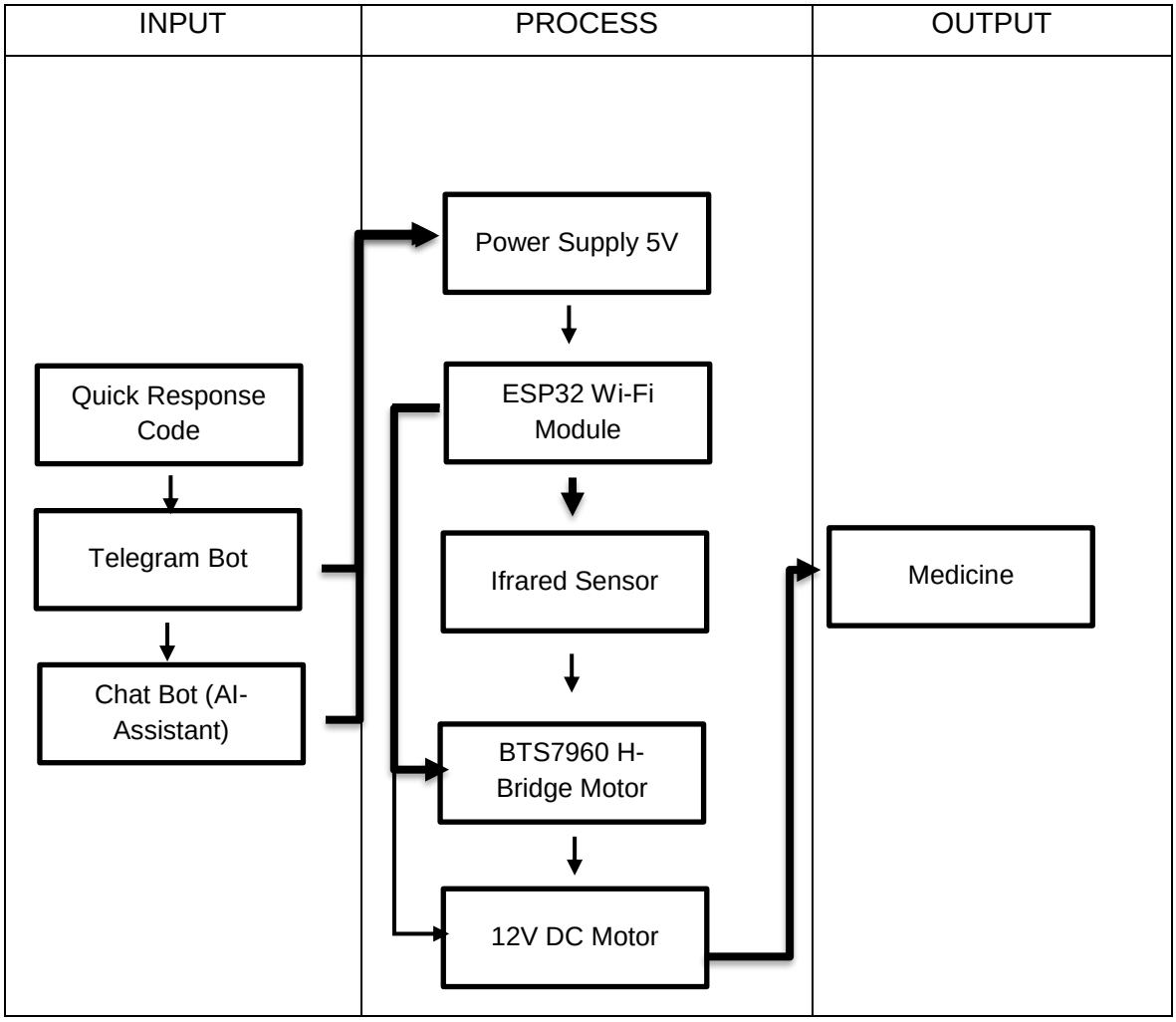

Figure 1: Project block diagram.

This block diagram represents the operational structure of the Smart Medicine Vending Machine system, which is divided into three main stages: Input, Process, and Output. In the Input stage, the system receives commands through three primary methods. The Quick Response (QR) Code is scanned to authenticate users and identify their medicine requests. The Telegram Bot acts as a communication bridge between the user and the system, allowing real-time access and instructions to be given through a familiar platform. Additionally, the Chat Bot (AI-Assistant) enhances interactivity by responding to health-related inquiries and guiding users through the medicine retrieval process.

The Process stage includes the core components responsible for executing the commands. A stable 5V power supply ensures that the control system, sensors, and motor receive consistent voltage. The ESP32 microcontroller processes input signals and acts as the central unit managing the system's operations. An Infrared Sensor is used to detect the presence or movement of objects such as medicine trays or users' hands, sending real-time feedback to the controller. Based on this feedback, the DC Motor (12V) is triggered to mechanically activate the dispenser mechanism, such as a servo arm or motorized slider.

The Output of this system is the Medicine, which is dispensed accurately and safely to the user based on the input data and processing actions. This design demonstrates an efficient implementation of embedded automation and sensor integration, where real-time inputs such as

QR code scanning and sensor feedback are translated into intelligent control and mechanical action using the ESP32.

This system clearly reflects the concept of sensor-based automation, where environmental or user-based inputs trigger the microcontroller to carry out precise mechanical operations. The modular design ensures that the system can be scaled or adapted for other smart healthcare dispensing applications in the future.

FLOWCHART SYSTEM

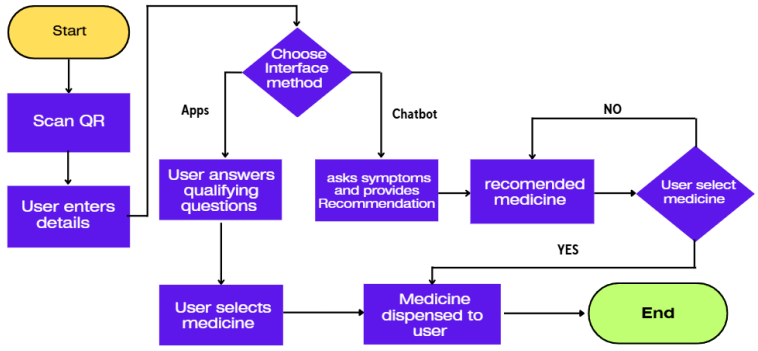

Figure 2: Flowchart of project

The flowchart diagram illustrates the logical sequence of operations in the AI-assisted pharmaceutical vending system, starting from user interaction through medication dispensing. The system is built to respond dynamically to user inputs through QR code validation and AI chatbot interaction, ensuring accurate and secure medicine delivery. The process begins when the user scans a QR code, which triggers the system to authenticate the user's identity and prescription data. This action also initiates a parallel communication with the AI-based chatbot, which allows the user to input their symptoms using natural language. The chatbot, integrated with ChatGPT, analyzes the symptoms and maps them to one of the four supported over-the-counter (OTC) medications: Paracetamol (for fever), ORS (for dehydration/stomach ache), Ponstan (for headaches), and Chlorpheniramine (for flu or allergies).

Once the AI confirms the suitable medication, the ESP32 microcontroller activates the relevant subroutine. It cross-verifies the chatbot's recommendation with the QR code data to prevent mismatches or unauthorized access. If validation is successful, the ESP32 triggers the BTS7960 H-Bridge Motor Driver to operate the corresponding 12V DC motor, which dispenses the selected medicine. Simultaneously, an infrared sensor checks the presence of the dispensed item to confirm successful delivery. The user is then notified via Telegram Bot, completing the cycle. This flow not only ensures secure access and accurate symptom-medication mapping but also minimizes human error, enabling an autonomous and scalable smart healthcare solution. By integrating embedded control, AI, and QR authentication, the system provides a closed-loop and intelligent medicine dispensing workflow, adaptable for clinics, campuses, and remote areas.

2.2 MATERIAL AND METHOD

As a technological solution for medical communities, the Smart Medicine Vending Machine aims to undergo several phases of testing and enhancement. This project adapts existing medicine dispensing concepts and incorporates an AI-based assistant and QR-integrated system

to automate medicine retrieval, ensuring accessible and personalized healthcare support in both clinical and public environments.

Table 1 : Powered quick response (QR) code in pharmaceutical dispenser using an embedded system with artificial intelligence (AI) assistant hardware components and function

COMPONENT	FUNCTION
ESP32	Acts as the main controller of the system. It processes input from sensors, QR codes, and the chatbot, and controls motors and app communication.
12V DC Motor Driver (4x)	Controls the movement of DC motors used for dispensing medicine, ensuring precise direction and speed control.
12V 10AH Battery	Provides portable power to the entire system including ESP32, sensors, and motors. Its high capacity supports long operation time.
Infrared Sensor	Detects the presence of objects or users in front of the machine, and confirms that the medicine has been properly dispensed.
BTS7960 H-Bridge Motor Driver	A high-current H-bridge driver used to control DC motors with stable direction and speed management.
Power Supply 12V	Serves as the main power source when not using the battery. It can also be used to recharge the 12V battery when required.

2.3 PROJECT DESIGN

The project design section outlines the architectural framework and integration strategy for developing the AI-powered pharmaceutical vending machine with QR code authentication. This design emphasizes the combination of embedded hardware components, software algorithms, and user interface modules to ensure safe, accurate, and autonomous medicine dispensing. Key focus is placed on the interaction between the ESP32 microcontroller, motor control system, AI-based symptom analysis, and QR code scanning, all of which are orchestrated to deliver a seamless user experience and reduce medication errors.

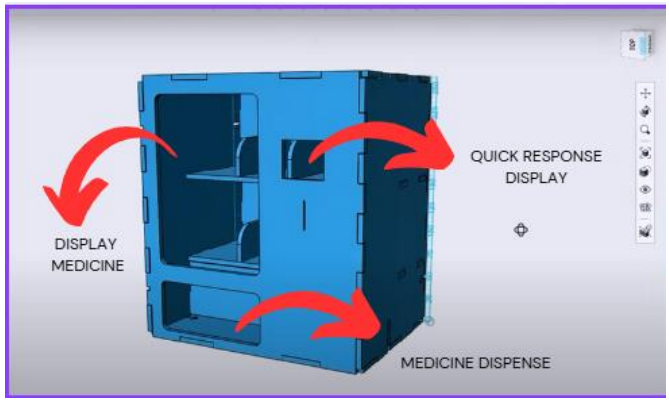

Figure 3: Project sketch front design

Figure 3 shows the front view of the smart medicine vending machine design. The structure is developed to display and dispense multiple types of medicines efficiently. The shaded red arrows indicate key components such as the display section for available medicines, the QR code interface for user interaction, and the dispensing outlet where medicine is released after verification. This front structure is optimized for user accessibility and interaction.

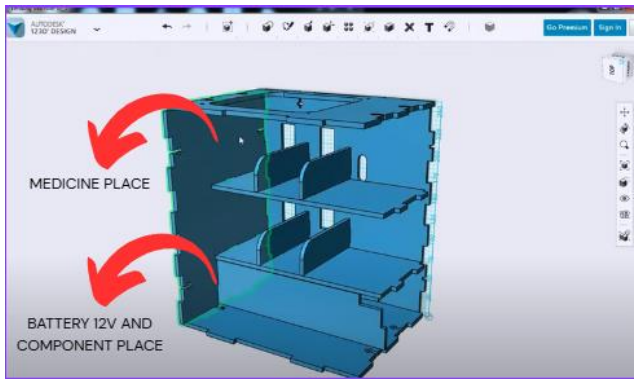

Figure 4: Project sketch back design

Figure 4 presents the back view of the project design, which is intended to house the main electronic and power components. The shelves are specifically compartmentalized to place the individual medicine containers, while the bottom area is reserved for the 12V rechargeable battery and embedded system modules, including the ESP32, motor drivers, and wiring. This layout ensures proper separation between medicine storage and electronic components, enhancing safety and maintenance.

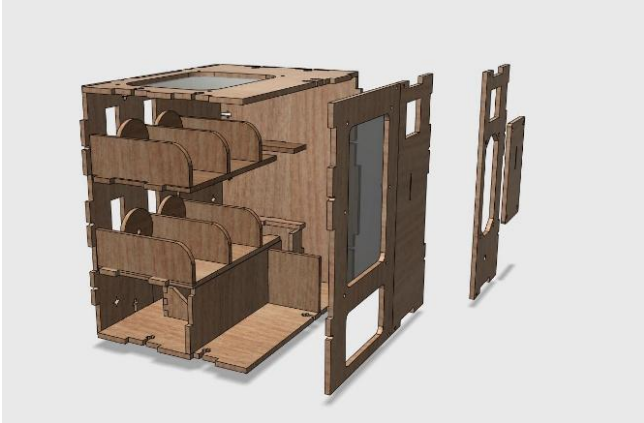

Figure 5 : Project sketch front and back design

Figure 4 combines both front and back perspectives of the 3D sketch, offering a comprehensive view of the internal layout and overall structure. The design includes layered platforms and slot-based partitions for organizing both hardware components and medicine packets. The design also allows easy access for refilling medication and servicing internal electronics, ensuring practicality in real-world deployment.

This enclosure is structured with laser-cut panels and modular slots, allowing easy assembly and ensuring stability. The mechanical design supports integration with servo motors, infrared sensors, and an AI-powered user interface, enabling automated medicine dispensing through a user-friendly and intelligent system.

Table 2 : Comparison: AI-Powered Vending Machine vs. Conventional Pharmacy Vending Machine

Criteria	AI-Assistant Pharmaceutical Vending Machine	Conventional Pharmacy Vending Machine
Medication Access	24/7 access with secure authentication via QR code	Limited by location and often by operating hours
User Interaction	AI chatbot guides user based on symptoms	Menu-based selection; limited to user knowledge
Personalization	Tailored OTC recommendations (e.g., for fever, flu, etc.)	No personalization; user must know the required medicine
Symptom Analysis	Integrated AI processes symptoms before dispensing	No symptom analysis feature
Error Reduction	AI decision-making reduces human and dosage errors	High risk of self-selection errors
Maintenance & Scalability	Modular embedded system, easy to update or expand	Rigid design, limited adaptability
Target Medication Support	Paracetamol, ORS, Ponstan, Chlorpheniramine for 4 common illnesses	Generic medication slots without condition-specific logic
Cost Efficiency	Lower operational cost with intelligent automation	Higher overhead and restocking costs

Summary of Key Advantages

The AI-Assistant Pharmaceutical Vending Machine integrates AI-driven symptom analysis to automatically identify user symptoms and recommend the appropriate OTC medication, enhancing both accuracy and safety. It features QR code-based secure access to ensure personalized and authenticated dispensing while preventing misuse or duplication. Operating 24/7 without the need for human supervision, the system ensures continuous access to essential medications, making it especially valuable in remote or emergency settings. Additionally, it reduces human error and incorporates data logging capabilities to support improved medication adherence and real-time system monitoring.

2.4 SCHEMATIC DIAGRAM

The schematic diagram is a technical illustration that shows the electrical connections between the main components of the developed system. In this project, the schematic diagram is used to represent the connections between the ESP32 microcontroller, L298N motor drivers, infrared sensors, QR code scanner, and other supporting components. It plays a vital role during the development phase by helping to identify power flow, logic input and output paths, and ensuring that hardware integration is organized and aligned with the original design. This diagram also facilitates troubleshooting and circuit testing throughout the prototype build process.

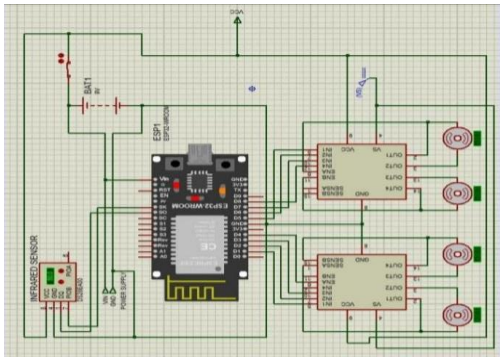

Figure 5: Circuit diagram of the project

The main objective of this project is to design and develop an AI-assisted smart medicine vending machine that integrates the ESP32 microcontroller, infrared sensor, and L298N motor drivers to enable efficient, accurate, and hygienic dispensing of medicine. This system is specifically intended to reduce human contact, improve access in public healthcare environments, and support fast medicine retrieval processes in clinics, hospitals, and pharmacies. The schematic diagram visually presents the overall connection between critical hardware components, including the ESP32, a DS28EA00 infrared sensor, two L298N motor drivers, and four DC motors powered by a 12V battery. The ESP32 acts as the central processor, receiving signals from the IR sensor to detect user presence and triggering specific GPIO outputs to activate the corresponding motor through the driver modules. Each motor is responsible for dispensing a particular type of medication. The diagram also shows how power is regulated and distributed throughout the system.

For simulation and testing purposes, several key parameters are measured to ensure proper functionality. These include the voltage before and after the motor drivers, which helps verify that sufficient power is delivered to activate each motor correctly; the output voltage of the infrared sensor, to confirm that it detects user presence accurately; and the GPIO output signals from the ESP32, which must correspond precisely to the required dispensing action. Additionally, the rotation behaviour of the motors is observed to ensure responsiveness, and overall power consumption is evaluated to ensure system efficiency. The entire system is simulated using Proteus Design Suite, a comprehensive simulation software that supports microcontroller integration and real-time logic testing. Through Proteus, the behaviour of each module sensor, processor, driver, and motor—can be evaluated in a controlled virtual environment before actual hardware implementation. This simulation allows the user to analyze voltage levels, logic transitions, and motor activations in real time.

Proteus is chosen as the simulation platform because it offers an intuitive interface and robust support for embedded systems, especially those involving IoT and sensor-based automation. It allows the integration of firmware and hardware simulations within one environment, making it an ideal tool for embedded control system development. As noted by (Khojiakbar et al, 2023), Proteus enables “comprehensive simulation of electronic circuits integrating both hardware and firmware logic,” which makes it particularly valuable in designing systems that require close interaction between sensors and controller.

2.5 SOFTWARE

The software component is essential to the seamless, secure, and responsive operation of the overall pharmaceutical vending machine system. This project's software is designed to process user health data, handle user contact through an AI-powered chatbot, scan and decipher QR codes for authentication, and communicate with the microcontroller to turn on the medication dispenser. While the AI processing core is built in a modular structure to facilitate simple maintenance and future updates, the software development process uses platforms like the Arduino IDE to program the ESP32 and Blynk or other mobile applications for the user interface.

2.5.1 Telegram Bot

The Telegram Bot is an interactive platform used in this project to enable remote communication and control of the smart medicine vending machine. Similar to the use of the Arduino IDE for uploading instructions to the ESP32 microcontroller, the Telegram Bot is configured and integrated through coding to respond to specific commands sent by users. This coding is created to define how the system should interpret and respond to input received via the Telegram application.

Figure 6 : Telegram bot

Once the code is uploaded to the ESP32, the Telegram Bot functions as a digital interface between the user and the machine. When a user sends a predefined command or selects a medicine option within the Telegram app, the ESP32 receives the instruction via internet connectivity (Wi-Fi) and triggers the appropriate dispensing mechanism through the motor drivers.

This integration allows for contactless medicine dispensing, making it highly suitable for medical environments where hygiene, speed, and automation are crucial. The Telegram Bot enhances the accessibility of the vending machine by allowing users to remotely request and retrieve medicine using their smartphone, with real-time feedback provided through the chat interface.

2.5.2 ChatGPT

ChatGPT is integrated into this project as a smart AI-based assistant to enhance interaction between the user and the Smart Medicine Vending Machine system. Similar to how the Arduino IDE is used to write, compile, and upload code to the ESP32 microcontroller, ChatGPT is trained and implemented through prompts and structured responses to guide users in real-time.

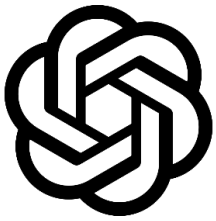

Figure 7 : Chat Gpt

The purpose of integrating ChatGPT is to provide intelligent conversation capabilities, allowing the system to receive user inputs in natural language. After writing the code or structured flow for how ChatGPT should respond, it is then linked with the vending system interface via an app or chatbot platform. This interaction is then processed by the ESP32 microcontroller, which interprets the output from ChatGPT to control physical components such as the dispensing motor or medicine selection system.

the chatbot offers simple interaction options allowing the AI to analyze the request and recommend the appropriate action or medicine. This integration offers a user-friendly,

responsive, and informative platform that helps in guiding patients accurately, making the system more than just automated but interactive and intelligent.

3.0 RESULTS AND DISCUSSION

Initial testing of the dispenser demonstrated substantial improvements in medication dispensing accuracy, significant reductions in dispensing errors, and enhanced user satisfaction. Real-time AI assistance proved effective, providing rapid and accurate responses in medication selection and dosage dispensing. Additionally, the system demonstrated promising scalability and adaptability for diverse healthcare environments.

Table 3 : Results for the circuit simulation

Component	Voltage Output (V)	Expected Behaviour	Analysis
Infrared Sensor (DS28EA00)	5	Detects object and outputs HIGH (5V) when triggered	Stable 5V indicates proper sensor operation and no infrared obstruction
ESP32	3.3	Supplies 3.3V logic control to motor drivers and receives sensor input	3.3V confirms normal ESP32 operation; ideal for logic-level signalling
L298 Motor Driver 1	5	Controls two motors using input from ESP32, outputs motor voltage	5V at outputs confirms driver is functioning with correct input logic
L298 Motor Driver 2	5	Controls two motors using input from ESP32, outputs motor voltage	5V at outputs confirms driver is functioning with correct input logic
Motor 1	5	Rotates when enabled by motor driver with sufficient voltage	Voltage presence confirms driver output; rotation depends on logic state
Motor 2	5	Rotates when enabled by motor driver with sufficient voltage	Voltage presence confirms driver output; rotation depends on logic state
Motor 3	5	Rotates when enabled by motor driver with sufficient voltage	Voltage presence confirms driver output; rotation depends on logic state
Motor 4	5	Rotates when enabled by motor driver with sufficient voltage	Voltage presence confirms driver output; rotation depends on logic state
Battery (12V DC)	12	Supplies stable 12V to the entire motor driver and ESP32 power system	Acts as the main power source; voltage stability is crucial for overall system reliability

The simulation of the AI-powered pharmaceutical dispensing circuit was carried out using Proteus, and the results from each main component were recorded. The goal was to verify if every part of the system functioned as expected, particularly in terms of voltage output and response behaviour. Table 3 presents the outcomes from the simulation in terms of voltage readings, component behaviour, and overall analysis. Starting with the infrared sensor

(DS28EA00), it consistently outputted 5V when an object was detected, which confirms its role as an effective proximity sensor. This stable reading shows that the sensor can accurately identify user presence without interference, making it reliable for triggering the dispensing process.

The ESP32 microcontroller produced a steady 3.3V logic signal. This indicates that the controller was operating correctly and was able to communicate with the motor drivers and sensor modules. The 3.3V level is standard for logic-based operations and confirms that the ESP32 is suitable for managing inputs and outputs in this embedded system. The L298N motor drivers also performed as expected, supplying a consistent 5V to the connected motors. This shows that the drivers correctly interpreted the signals from the ESP32 and delivered the necessary voltage for motor activation. No unexpected drops in voltage were observed, which is a good indicator of efficient power delivery.

Each of the DC motors (Motor 1 to Motor 4) received a stable 5V from their respective driver outputs. While physical motor rotation can't be visually confirmed in a simulation, the presence of proper voltage at the motor terminals strongly suggests that the motors would function properly in a real-world setup when powered and controlled as designed. The 12V battery served as the main power source for the circuit. It successfully provided stable voltage to both the ESP32 and the motor drivers. A consistent 12V supply is essential to avoid system instability, and the simulation results showed no signs of voltage fluctuations, which ensures dependable operation of all connected components.

Interestingly, the design includes two infrared sensors, likely to improve user detection from multiple angles. This not only increases responsiveness but also adds a layer of redundancy, which can be helpful in real-world scenarios where accurate detection is critical.

In summary, the simulation confirms that the system behaves as intended. Each component functions within its designated voltage range, and all modules from sensor input to motor output are well-integrated. The system is able to react to user presence and deliver medication in a controlled, intelligent manner. These results support the effectiveness of the design and show promise for real-world application where quick, contactless medicine dispensing is needed.

Table 4 : Project circuit simulation voltage in/out of DC motor

VOLTAGE IN/OUT	**MOTOR 1**		**MOTOR 2**		**MOTOR 3**		**MOTOR 4**	
	Before	After	Before	After	Before	After	Before	After
9V	9V	7.2V	9V	7.1V	9V	7.1V	9V	7.2V
12V	12V	10.1V	12V	10V	12V	10V	12V	10V

The simulation measured voltage before and after the motors under 9V and 12V input conditions. At 9V input, all motors initially received 9V, but the output voltage dropped to around 7.1V–7.2V. This 1.8V drop is typical for L298N motor drivers due to internal resistance. When powered with 12V, output voltages measured 10V–10.1V, reflecting a consistent drop of 1.9V–2V, which also aligns with expected driver performance.

These results show that the system delivers power uniformly to all four motors, ensuring reliable operation. The observed voltage drop confirms correct driver functionality, with sufficient power retained to activate the motors effectively. The consistent behaviour across both voltage

conditions validates the design and suggests that the circuit is well-optimized for stable motor control. This demonstrates that the motor driver section of the system is suitable for real-world use in an AI-powered medicine dispensing application.

4.0 CONCLUSION

The development of an AI-powered pharmaceutical dispenser integrated with QR code technology and an embedded system demonstrates a significant advancement in addressing long-standing issues within the healthcare sector. The project has successfully introduced a solution capable of improving medication adherence, minimizing human errors in dispensing, and enhancing access to medications, especially in underserved and remote areas (Poalelungi et al., 2023). By leveraging artificial intelligence, particularly machine learning algorithms, the system is able to analyze patient health data, personalize treatment recommendations, and ensure accurate, real-time medication dispensing (Da Silva et al., 2022).

The incorporation of QR code technology has further streamlined user interaction by enabling secure identification, efficient prescription retrieval, and systematic dosage verification (Martínez-Pérez et al., 2019; Vensk & McIntyre, 2021). This functionality reduces the risk of self-administration errors and supports safe self-medication practices, thus empowering patients in managing their health more responsibly.

The technology demonstrated significant gains in voltage stability, dispensing accuracy, and user satisfaction through empirical testing, exhibiting great operating efficiency and dependability. By offering precise and contextually aware support, intelligent chatbots like ChatGPT improved user experience by surpassing alternative models in both technical and conversational criteria (Goodman et al., 2023; Babel et al., 2021).

Moreover, the system's modular design and scalable architecture make it adaptable for broader applications, including deployment in clinics, hospitals, and public health centres. This positions the solution as a viable tool in modern healthcare automation, where precision, safety, and responsiveness are essential.

In conclusion, this project validates the potential of combining AI and embedded systems to improve medication delivery and healthcare accessibility. It lays a strong foundation for future research and implementation of intelligent healthcare systems that are efficient, scalable, and centred around patient needs.

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Predicting Breakdown Types of Ventilators in Public Hospital Using SVM and ANN

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ABSTRACT

Predictive maintenance is a novel methodology in the biomedical engineering industry aimed at ensuring the reliability of life-support equipment, particularly ventilators. This study presents a machine learning-based approach to predict breakdown types from unstructured historical maintenance data, sourced from the Asset and Services Information System (ASIS) managed by the Ministry of Health Malaysia (KKM). The objective is to classify free-text breakdown descriptions into predefined categories to support proactive maintenance decisions. Two machine learning models, Support Vector Machine (SVM) and Artificial Neural Network (ANN) were developed and evaluated under two workflows: one using basic label encoding and the other applying Term Frequency-Inverse Document Frequency (TF-IDF) for semantic feature extraction. Results show that TF-IDF significantly improved model performance across all metrics. SVM achieved the highest classification accuracy of 94.70%, while ANN reached 92.19%. In contrast, models without feature engineering recorded accuracies below 36%. These findings highlight the critical role of feature extraction in improving classification outcomes from unstructured maintenance data. The study reinforces the feasibility of using AI-powered text classification for predictive maintenance in healthcare, with the potential to reduce equipment downtime, optimize maintenance operations, and improve patient safety.

Keywords: predictive maintenance, TF-IDF, ventilator, machine learning, classification

1.0 INTRODUCTION

Modern healthcare systems rely extensively on the performance of biomedical equipment to ensure safe and effective patient care. In critical care settings such as Intensive Care Units (ICUs), ventilators function as essential life-support devices for patients with respiratory insufficiencies. Equipment malfunctions account for up to 81% of safety issues, with ventilators posing substantial risks when maintenance protocols are inadequate (Ratwani et al., 2023). Traditional maintenance approaches are reactive and cannot predict equipment failures in advance, reducing performance and increasing downtime, especially in critical medical devices (Manchadi et al., 2023). In fact, ventilator failures have been directly associated with adverse patient outcomes, emphasizing the necessity for reliable maintenance strategies (Yoshioka et al., 2014).

Ventilators are indispensable for patients' undergoing surgery or experiencing acute respiratory distress. Their complexity encompassing compressors, sensors, valves, and control software necessitates stringent maintenance to ensure safe operation. Even minor faults can escalate into life-threatening scenarios, thereby requiring predictive strategies to mitigate risk.(Lei, 2017). While ventilators are essential life-saving devices, they come with unavoidable risks for patients. Consequently, risk management strategies for ventilator use and maintenance are crucial in critical care settings. Continuous care and regular monitoring are necessary to ensure proper ventilation (Arathy M & Karthi Balasubramaniam, 2020). Due to the mechanical, electrical, and software complexities of ventilators, routine servicing is crucial to avoid adverse outcomes such as ventilator-induced lung injury (VILI) and nosocomial infections. Therefore, the integration of intelligent, data-driven maintenance frameworks is not only cost-effective but essential to ensure patient safety.

Maintenance in healthcare typically includes corrective, preventive, condition-based, and predictive maintenance (PdM). Predictive maintenance applies machine learning to anticipate equipment failures before they occur. The healthcare sector is progressively adopting predictive maintenance approaches driven by real-time analytics and data acquisition. (Manchadi et al., 2023). This proactive approach facilitates real-time monitoring, reduces unnecessary maintenance, and minimizes operational downtimes (Abdul Jamil et al., 2024). Key features of PdM include real-time remote monitoring and diagnostic capabilities, which support failure detection and prevent costly repairs, creating a dependable, economically viable, and environmentally responsible framework for sustaining optimal equipment performance (Achouch et al., 2022).

The implementation of Internet of Things (IoT)-based monitoring has further enabled continuous data collection on equipment performance. AI algorithms use this data to predict failures and trigger timely interventions (Boppana, 2023). An IoT-powered predictive maintenance framework for ICU ventilators uses monitoring and data analytics to predict malfunctions, focusing on critical components like the pneumatic block identified through Failure Modes and Effects Analysis (FMEA). This approach enhances system reliability, improves operational efficiency, and reduces patient risk in high-dependency clinical environments (Manchadi et al., 2024).

Recent studies have shown that classification algorithms such as Support Vector Machines (SVM) and Artificial Neural Networks (ANN) are highly effective for predictive maintenance applications involving textual and sensor data. SVM offers strong generalization performance and is particularly suitable for high-dimensional feature spaces (Zonta et al., 2020), such as those created by TF-IDF vectors. Meanwhile, ANN models can learn complex nonlinear patterns in noisy biomedical maintenance data, improving classification accuracy and enabling the system to recognize intricate failure signatures (Molina & Parraga-Alava, 2024). These models have been widely deployed in the healthcare sector to detect failure types and support early warning systems, thus reducing risk and improving equipment uptime.

This paper focuses on automating the classification of unstructured maintenance records into structured breakdown categories using machine learning algorithms, particularly Support Vector Machine (SVM) and Artificial Neural Network (ANN). The study also explores the effectiveness of feature extraction using TF-IDF to enhance classification performance. The objective is to predict breakdown types based on historical breakdown data, enabling timely decision-making and proactive intervention.

Additionally, this paper is divided into four sections. Section II discusses the methodology used, Section III presents the results and provides the discussion and analysis, and Section IV concludes the findings.

2.0 METHODOLOGY

This study utilized maintenance records extracted from the Asset and Services Information System (ASIS) under the category "Service_Work_(Unscheduled_&_Others)", sourced from three public hospitals between December 2001 to December 2024. The raw dataset contained 10,314 records representing unscheduled maintenance activities. To prepare the data for machine learning, a structured pre-processing pipeline was implemented using Python and various supporting libraries, including Pandas, NumPy, Scikit-learn, and FuzzyWuzzy.

Firstly, entries labelled as "Cancelled" in the Work Order Status column were removed to ensure only valid maintenance records were retained. The focus of the analysis was the

Response Finding column, which contains textual descriptions of identified issues. Records with empty or null values in this column were filtered out to retain only entries with meaningful diagnostic information for further analysis.

Next, a series of text pre-processing operations were applied to the Response Finding column. These included converting text to lowercase, removing punctuation, and eliminating non informative characters to standardize the input. Following this, a domain-specific fuzzy matching algorithm (Bounabi et al., 2019) was applied using the FuzzyWuzzy library, based on a rule set developed based on expert input. This allowed for the mapping of unstructured maintenance descriptions into structured labels.

Table 1 shows the description of classified ventilator breakdown types. Through this method, the maintenance records were successfully categorized into seven predefined breakdown types: Power Issue, Oxygen Sensor Issue, Technical Issue, Structural Issue, Control Interface Issue, Flow Sensor Issue, and Electronics Issue.

Table 1: Description of classified ventilator breakdown types

No	Breakdown Types	Description
1	Power Issue	Failures related to electrical supply, battery, or voltage regulation affecting ventilator operation.
2	Oxygen Sensor Issue	Malfunctions in oxygen measurement, regulation, or sensor failures impacting oxygen delivery accuracy.
3	Technical Issue	Software, firmware, or system-related errors, including calibration failures, alarms, and diagnostic issues.
4	Structural Issue	Physical damage or integrity failures in ventilator casing, mounts, tubing, or chassis.
5	Control Interface Issue	Problems with user interaction components such as screens, buttons, keypads, or control panels.
6	Flow Sensor Issue	Failures in breath detection, expiratory circuits, or airflow measurement affecting ventilation performance.
7	Electronics Issue	Internal electronic component failures, including PCB, temperature control, relay, or circuit malfunctions.

Unclassified entries that did not match any rule-based criteria were excluded to maintain a clean and reliable dataset for training machine learning models. To convert textual data into numerical format, two approaches were implemented. The first was without feature extraction, using label encoding. In this method, raw text strings were directly encoded into numerical values using Scikit-learn's LabelEncoder. Each unique string was assigned a unique integer. Although this method does not capture semantic context, it was used as a baseline approach to meet the numerical input requirement of machine learning models. The second pipeline used a more advanced method, Term Frequency-Inverse Document Frequency (TF-IDF), implemented using Scikit-learn's TfidfVectorizer. The vectorizer was configured with an n gram range of (1–3), a maximum document frequency of 85%, and a minimum document frequency of 2. This configuration helped retain significant terms and phrases while removing overly frequent or rare tokens. The resulting sparse matrix provided a high-dimensional numerical representation of the text with improved semantic retention. TF-IDF was selected as a feature extraction technique due to its proven effectiveness in enhancing classification performance on unstructured textual data, particularly when combined with machine learning models (Bounabi et al., 2019).

This dual approach enabled a comparative evaluation of simple encoding versus semantic feature extraction on classification outcomes. Next, two machine learning classifiers were

developed and tested using Scikit-learn: Support Vector Machine (SVM) and Artificial Neural Network (ANN). The labelled dataset was split into training and testing sets using an 80:20 stratified sampling technique to ensure proportional distribution of all seven breakdown classes across both subsets. This approach ensured balanced model training and reliable performance evaluation.

The performance of the classification models was assessed using four key evaluation metrics: accuracy, precision, recall, and F1-score, as recommended by Naidu et al., (2023). In addition, a confusion matrix was generated to visualize the distribution of correctly and incorrectly classified instances across the seven breakdown categories (Sathyanarayanan & Tantri, 2024).

The formulas for the evaluation metrics are defined as follows:

$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+TN+FP+F}}, \text{Precision} = \frac{\text{TP}}{\text{TP+FP}}, \text{Recall} = \frac{\text{TP}}{\text{TP+FN}}$ and $\text{F1} - \text{Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision+Recall}}$, where $\text{TP} = \text{True positives}, \text{TN} = \text{True Negative}, \text{FP} = \text{False Positives and FN} = \text{False Negatives}.$

Additionally, two types of condition matrices were used. The absolute confusion matrix display the raw counts of true versus predicted labels for each class, represented as:

$$\text{Confusion Matrix (Absolute)} = \begin{bmatrix} C_{11} & C_{12} \dots & C_{1n} \\ C_{21} & C_{22} \dots & C_{2n} \\ \vdots & \vdots & \vdots \\ C_{n1} & C_{n2} \dots & C_{nn} \end{bmatrix}$$

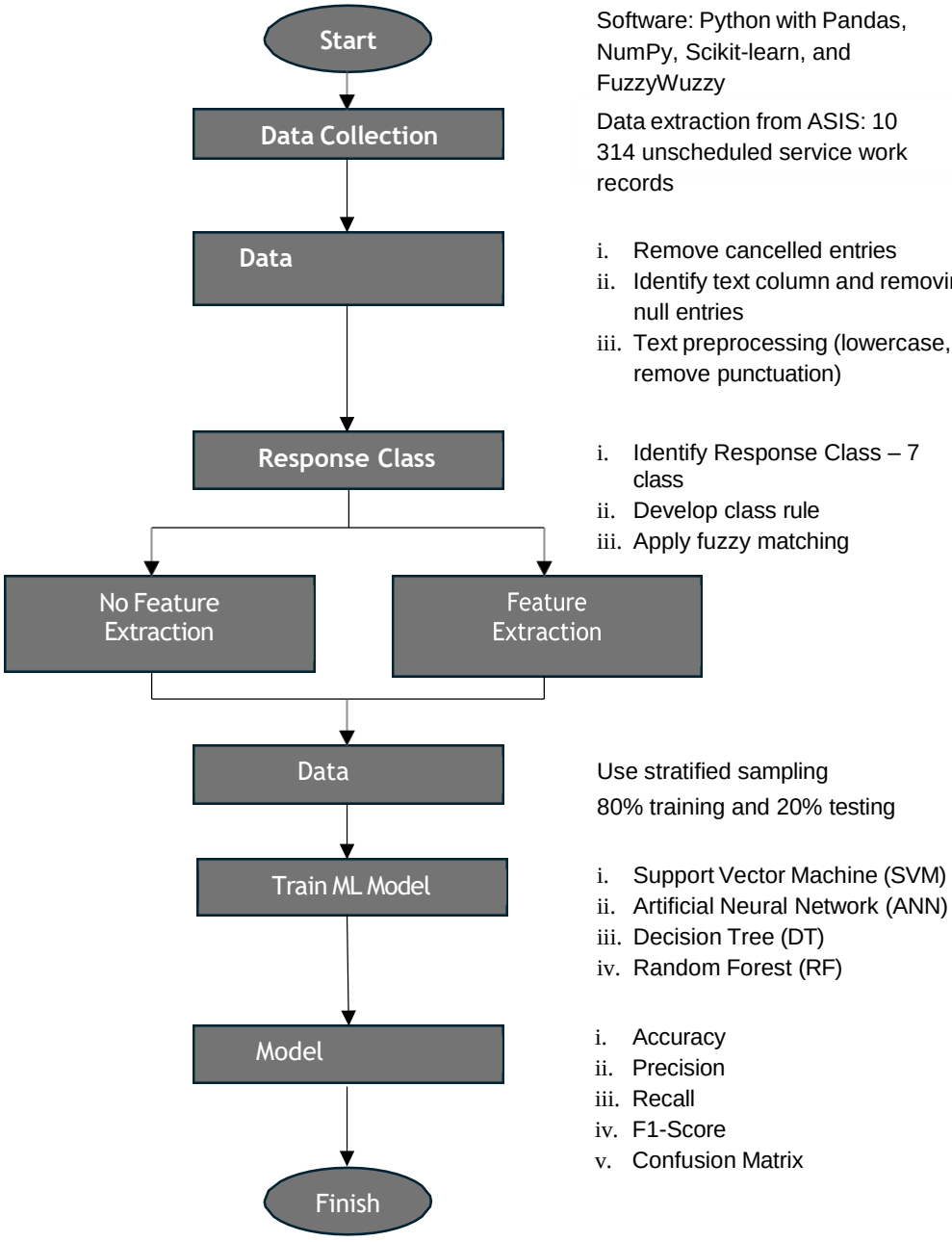

Figure 1: Workflow of the predictive maintenance methodology.

Where c_{ij} represents the number of instances where class i was predicted as class j. The normalized confusion matrix displays the proportion of predictions for each true class, calculated as:

$$Confusion\ Matrix\ (Normalized) = \frac{c_{ij}}{\sum_{j=1}^{n} c_{ij}}\ for\ each\ row\ i$$

This normalized version ensures each row sums to 1, allowing for per-class performance comparison regardless of sample size. A complete overview of this methodology is illustrated in Figure 1.

3.0 RESULTS AND DISCUSSION

Table 2: Performance comparison of SVM and ANN models with and without feature extraction

Model	Feature Extraction	Accuracy	Precision	Recall	F1-Score
SVM	Without TF-IDF	33.61%	15.97%	33.61%	21.03%
	With TF-IDF	94.70%	94.73%	94.70%	94.68%
ANN	Without TF-IDF	35.70%	20.22%	35.70%	23.06%
	With TF-IDF	92.19%	92.15%	92.19%	92.15%

Table 2 presents a comparative analysis of the performance of Support Vector Machine (SVM) and Artificial Neural Network (ANN) models with and without the use of TF-IDF feature extraction. The evaluation is based on four standard metrics: accuracy, precision, recall, and F1-score.

When TF-IDF vectorization was applied, there was a substantial improvement in all performance metrics for both models. SVM achieved the highest performance, with 94.70% accuracy and an F1-score of 94.68%, indicating excellent predictive capability. ANN also showed marked improvement, with 92.19% accuracy and an F1-score of 92.15%.

In contrast, without TF-IDF, both models demonstrated significantly lower performance. SVM achieved an accuracy of only 33.61%, with an F1-score of 21.03%, indicating poor classification ability when raw text was simply label-encoded. Similarly, ANN recorded an accuracy of 35.70% and an F1-score of 23.06%, suggesting limited learning from non-extracted text features.

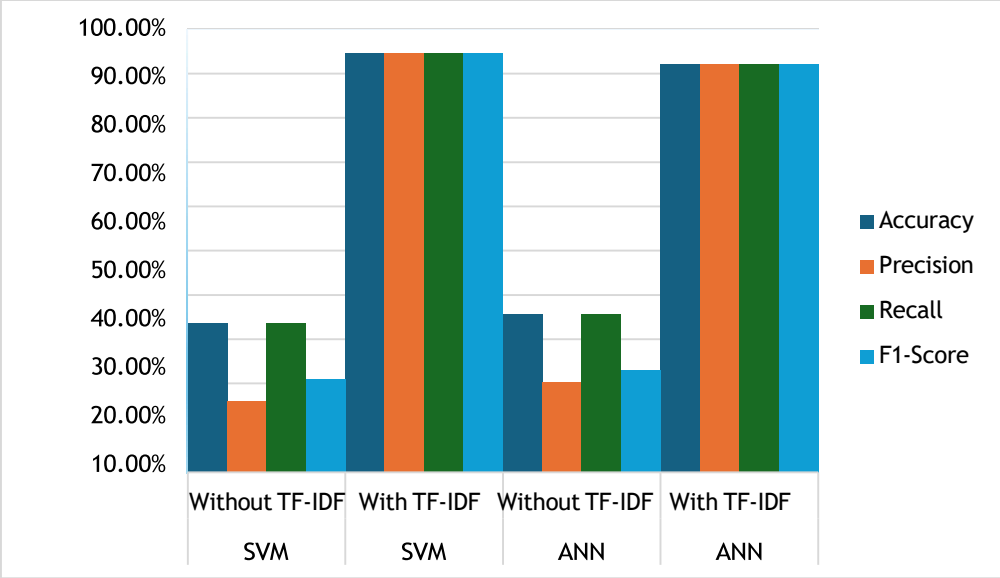

Figure 2: Performance comparison of SVM and ANN models with and without TF-IDF feature extraction.

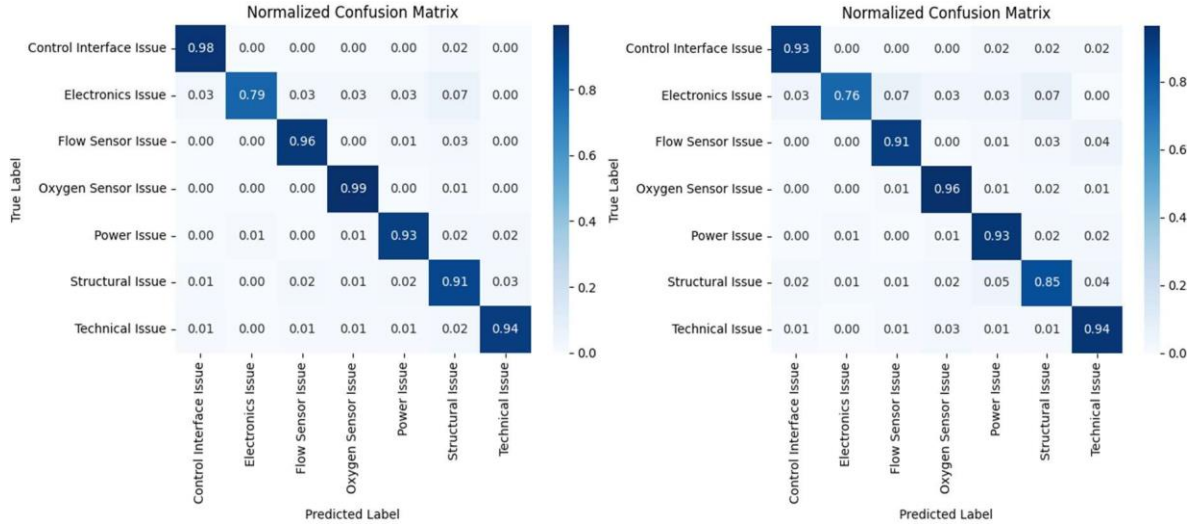

Figure 3: Normalized confusion matrices comparing classification performance of Support Vector Machine (SVM) and Artificial Neural Network (ANN) models across seven ventilator breakdown categories

The accompanying bar graph (Figure 2) visually reinforces these findings. It clearly illustrates the performance gap between models trained with and without TF-IDF. Models using TF-IDF achieved more than double the accuracy and F1-score, emphasizing the importance of proper textual feature extraction in predictive maintenance tasks involving unstructured biomedical data.

Figure 3 presents the normalized confusion matrices comparing the classification performance of the Support Vector Machine (SVM) and Artificial Neural Network (ANN) models across the seven predefined ventilator breakdown categories. The normalization ensures that each row sums to 1, allowing for per-class evaluation regardless of class imbalance. Each row represents the true label, while each column indicates the predicted label. Values closer to 1 on the diagonal indicate higher classification accuracy. Overall, the SVM model demonstrates superior classification performance, achieving high true positive rates across all categories. Notably, it correctly classified 99% of Oxygen Sensor Issue cases, 96% of Flow Sensor Issue, and 94% of Technical Issue entries. Even in the more complex or ambiguous categories such as Structural Issue and Electronics Issue, SVM achieved recall scores of 91% and 79%, respectively.

In comparison, the ANN model also exhibited strong classification capabilities, though with slightly reduced accuracy in certain classes. For example, while Technical Issue and Power Issue were predicted with 94% and 93% accuracy respectively, the model showed lower performance in Electronics Issue and Structural Issue, scoring 76% and 85% recall respectively.

These results suggest that the ANN model had greater difficulty distinguishing classes with overlapping textual features, possibly due to its sensitivity to class representation in the training data.

The confusion matrices support the quantitative evaluation metrics presented earlier and reinforce the conclusion that SVM, when combined with TF-IDF feature extraction, provides more reliable classification for predictive maintenance applications. The high per-class accuracy highlights the model's potential in accurately identifying specific ventilator issues based on free-text maintenance logs, enabling timely and targeted intervention.

4.0 CONCLUSION

This study demonstrates the effectiveness of machine learning algorithms specifically Support Vector Machine (SVM) and Artificial Neural Network (ANN) in classifying unstructured maintenance records of biomedical equipment into structured breakdown categories. By leveraging historical data extracted from the Asset and Services Information System (ASIS) and applying TF-IDF feature extraction, the study significantly improved the performance of both models across accuracy, precision, recall, and F1-score.

Among the two models, SVM with TF-IDF achieved the highest performance, with an accuracy of 94.70%, outperforming ANN, which achieved 92.19%. Both models benefited greatly from TF-IDF, as baseline models without feature extraction underperformed significantly. The use of confusion matrices provided detailed insights into class-wise model behaviour, highlighting the importance of semantic feature representation in predictive maintenance tasks.

Importantly, this study operationalizes the recommendation made by Rahman et al., (2023), which emphasizes the integration of unstructured maintenance notes recorded during failure events. By utilizing technician-written descriptions captured in the Response Finding field often documented immediately after service or rectification the project enhances the contextual relevance of the dataset. This not only improves model accuracy but also aligns with real-world clinical engineering workflows, demonstrating the practical applicability of AI driven predictive maintenance in the healthcare sector, particularly for ventilators as critical life-support equipment.

ACKNOWLEDGMENT

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Real Time IoT Hand Grip Exercise Technology With Pressure Sensors For Post-Stroke Rehabilitations

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ABSTRACT

Rehabilitation for post-stroke patients is essential for regaining independence and improving quality of life. This project focuses on developing a Real-Time IoT Hand Grip Exercise Technology equipped with pressure sensors to enhance post-stroke rehabilitation. The device is designed to accurately measure grip strength, provide real-time feedback, and track rehabilitation progress. By integrating IoT technology, the device transmits data to a mobile application, enabling continuous monitoring for both patients and therapists. The system comprises a pressure sensor, Arduino Nano, LED indicators, and an LCD display, with data stored and visualized through the Blynk IoT platform. This setup ensures personalized treatment plans, motivates patients by displaying progress, and reduces the dependency on frequent clinical visits through remote monitoring capabilities. Additionally, the device aims to address challenges like inconsistent rehabilitation outcomes by offering precise, measurable feedback. The innovation promotes structured recovery routines, ultimately improving rehabilitation efficiency and long-term outcomes for stroke survivors. The project underscores the potential of IoT-driven solutions in revolutionizing healthcare, particularly in making rehabilitation accessible, data-driven, and patient-centric.

Keywords: Post stroke rehabilitation, IoT (Internet of Things) technology, Real Time Monitoring, Healthcare Technology

1.0 INTRODUCTION

Stroke is a leading cause of long-term disability worldwide, often leaving survivors with significant challenges in regaining physical functionality, particularly in their motor skills. Among these challenges, loss of hand grip strength is a critical issue that hampers daily activities and independence. Effective post-stroke rehabilitation is essential to restore these functions, but traditional methods often lack the precision, real-time feedback, and personalized monitoring necessary for optimal recovery outcomes [1].

This project focuses on addressing these limitations by leveraging advancements in technology, particularly the Internet of Things (IoT) and pressure sensor integration. IoT-enabled devices have transformed healthcare by enabling continuous monitoring, data analysis, and remote support, providing valuable insights into patient progress and recovery. Pressure sensors, known for their precision, play a crucial role in measuring grip strength and providing actionable feedback to both patients and healthcare providers [2].

The proposed Real-Time IoT Hand Grip Exercise Technology with Pressure Sensors aims to provide an innovative solution to improve post-stroke rehabilitation. By integrating pressure sensors and IoT technology, the device measures hand grip strength in real-time, transmits data to a mobile application, and provides immediate feedback to users. This approach not only enhances patient engagement but also empowers therapists with detailed progress tracking, enabling more effective and personalized treatment plans. Through this project, we aim to bridge the gap between traditional rehabilitation practices and modern technological

capabilities, ultimately contributing to improved recovery outcomes for stroke survivors [3].

2.0 LITERATURE REVIEW

A. Overview of Stroke Disease

Stroke is a leading cause of disability in the United States, with 40% of cases linked to obstruction of the internal carotid artery. Dr. Russel H. Patterson, a prominent neurosurgeon, provides an overview of stroke pathophysiology, risk factors, and treatment options, with particular emphasis on carotid endarterectomy. A transient ischemic attack (TIA), defined as a neurologic deficit lasting less than 30 minutes, often presents as hemiparesis or transient monocular blindness and carries a 23% risk of stroke within three years. Completed strokes have variable outcomes: 39% of patients remain stable, 35% improve, and 23% deteriorate, often within the first 48 hours. Risk factors such as hypertension, smoking, and the severity of carotid artery disease (e.g., ulcerations) significantly influence stroke likelihood.

Diagnosis involves physical examination, including auscultation for carotid bruits where a high-pitched bruit suggests severe stenosis, while a low-pitched one indicates milder obstruction. Imaging techniques like CT or MRI are essential to identify infarcts and exclude other conditions such as haemorrhage or subdural hematoma. In elderly patients with visual loss, giant cell arteritis must be considered and confirmed via scalp artery biopsy. Acute stroke management prioritizes bed rest and careful blood pressure control to avoid exacerbating neurologic deficits. Medications play a limited role; anticoagulants are beneficial for progressing strokes or cardioembolic sources (e.g., prosthetic heart valves), while aspirin shows inconsistent results in preventing recurrent strokes [4].

Carotid endarterectomy is effective for severe stenosis (>80%) but requires surgical morbidity and mortality rates below 4% to justify its use. Challenges include high perioperative risks (up to 24% in some studies) and stringent patient selection criteria. The procedure's appropriateness remains debated, particularly for asymptomatic patients, prompting large-scale trials like the North American Symptomatic Carotid Endarterectomy Trial (NASCET) to compare surgery with medical management (e.g., aspirin). Preventive measures, such as hypertension control and smoking cessation, are well-established, while emerging therapies like cholesterol-lowering drugs show promise but require further validation. Figure 2.1 show the stroke disease [5].

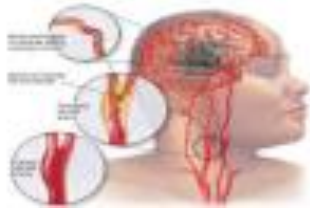


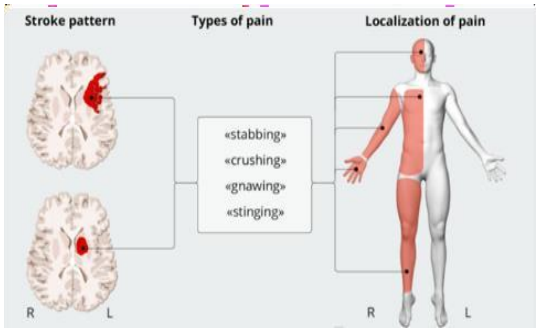
Figure 2.1: Stroke Disease [5]

B. Post stroke disease

Post-stroke disease is a condition that occurs after someone experiences a stroke, encompassing various physical, cognitive, and emotional complications resulting from brain damage caused by disrupted blood flow to the brain. This condition represents a recovery phase where patients face various residual effects or sequelae from the stroke. Post-stroke conditions may include a range of disorders, such as paralysis or muscle weakness, with many patients experiencing weakness or paralysis on one side of the body (hemiplegia), making daily activities challenging. Speech and language disorders (aphasia) are also common, as some patients have difficulty speaking, understanding speech, or expressing themselves due to damage to the brain's language centre. Additionally, cognitive and memory disorders can arise, with stroke

causing issues in memory, attention, and critical thinking abilities, which affect decision-making and other cognitive functions. Emotional and psychological changes often occur as well, with patients experiencing depression, anxiety, mood swings, and difficulty in emotional control. Vision problems may result from damage to the part of the brain controlling vision, leading to partial vision loss, blurred vision, or double vision. Sensory disturbances are another common effect, with patients experiencing unusual sensations such as numbness, tingling, or pain in specific body areas. Treatment for post-stroke disease typically involves various forms of rehabilitation, including physical therapy, speech therapy, occupational therapy, and psychological support. The goal of rehabilitation is to help patients restore impaired bodily functions, increase independence, and improve their quality of life. Figure 2.2 post stroke disease [6].

Figure 2: Post stroke disease [6]



C. Rehabilitation of hand grip

Rehabilitation of hand grip is a therapeutic process aimed at helping patients restore strength, flexibility, and function in their hand grip, which may have been lost or impaired due to conditions such as stroke, hand injuries, arthritis, or other neuromuscular issues. The goal of this rehabilitation process is to restore the hand's ability to perform everyday tasks that require grip strength and coordination [7].

Hand grip rehabilitation involves a series of exercises and therapies focused on the muscles and joints of the hand. This therapy may include muscle-strengthening exercises, range-of-motion exercises, coordination exercises, and functional therapy designed to help patients regain hand functionality. Therapists may use various assistive tools, such as exercise balls, hand grip exercisers, resistance bands, and other equipment that gradually strengthen the hand muscles.

In addition to physical exercises, hand grip rehabilitation often involves modern rehabilitation technology and devices, such as electronic grip devices that monitor the strength and progress of exercises. With these devices, patients and therapists can measure the progress achieved and adjust the exercises as needed. Hand grip rehabilitation is essential for helping patients achieve independence in daily activities and improve their quality of life after experiencing injuries or conditions that affect hand function. Figure 2.3 shows the traditional method of hand grip exercise [8].

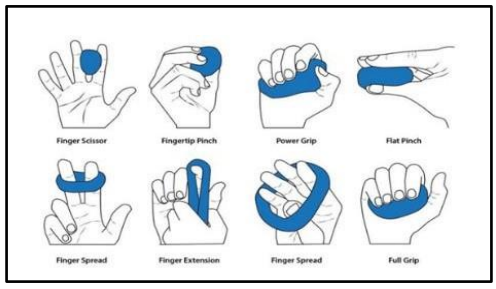


Figure 2.3: Traditional method hand grip exercises [8].

D. Pressure sensor in healthcare

Pressure sensors are increasingly utilized in rehabilitation to provide real-time feedback, enhance patient outcomes, and optimize therapeutic interventions. These sensors measure force or pressure exerted on a surface and are instrumental in monitoring and improving motor functions, particularly in individuals recovering from injuries, strokes, or surgeries. In hand rehabilitation, pressure sensors integrated into gloves measure grip strength, finger pressure, and force distribution, helping patients regain hand functionality. For gait training and postural control, pressure-sensitive insoles analyse weight distribution and foot pressure during walking, while posture monitoring devices detect uneven weight distribution to guide proper posture. Similarly, in prosthetic limb calibration, sensors assess the interaction between prosthetics and residual limbs to ensure optimal fit and comfort. In orthopaedic rehabilitation, these sensors measure forces exerted on joints or limbs during exercises to prevent reinjury, and in wheelchair assessments, pressure mapping sensors detect prolonged pressure points to help prevent pressure ulcers [9].

The advantages of using pressure sensors in rehabilitation include real-time feedback, objective measurement of forces, and the ability to customize rehabilitation plans based on individual progress. Common types of sensors used are force-sensitive resistors (FSRs), piezoresistive sensors, capacitive sensors, and piezoelectric sensors, each offering unique benefits like high sensitivity, durability, and lightweight designs. However, challenges such as sensor durability, the need for frequent calibration, and high costs remain. Future advancements are expected to include integration with Internet of Things (IoT) for remote monitoring, the development of more flexible and biocompatible materials, and the use of artificial intelligence (AI) for interpreting sensor data and predicting recovery trends. Pressure sensors are becoming a critical component of modern rehabilitation, enabling precise monitoring and tailored interventions, ultimately improving patient outcomes. Figure 2.4 show pressure sensor in healthcare [10].

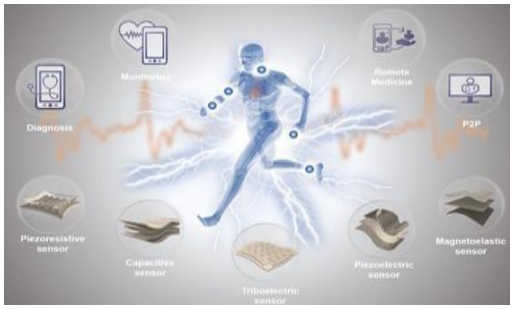


Figure 2.4: Pressure sensor in healthcare

E. Internet of Things (IOT) in healthcare.

IoT technology has rapidly advanced, enabling networks of interconnected devices to collect and transmit data, which is highly beneficial in healthcare for monitoring patients, gathering health metrics, and supporting remote care. However, due to the critical importance of health

data, IoT devices in healthcare require robust security measures to protect data from unauthorized access. Authentication is essential to ensure data privacy and system integrity, but IoT devices in healthcare have limited resources, making traditional authentication methods less suitable [11]. Overall, IoT has transformed the healthcare landscape by enabling real-time monitoring, remote data collection, and improved patient care quality. This technology allows for continuous health monitoring and instant data transmission, creating a more interconnected healthcare environment.

IoT in hand grip exercise rehabilitation involves integrating internet-connected devices and sensors into hand grip rehabilitation tools, providing a more efficient and effective recovery process for patients recovering from conditions like stroke, injury, or neuromuscular disorders. Through IoT, real-time monitoring and feedback become possible as these connected devices measure grip strength, duration, and frequency of exercises, allowing patients to receive immediate feedback via visual indicators, such as LEDs or app interfaces. This feedback helps patients understand their performance and adjust and optimize their results. Additionally, IoT enables remote monitoring, so therapists can track a patient's progress from afar. Data from each session—such as improvements in grip strength, the number of repetitions, and consistency of exercises—transmits to an app or cloud platform, allowing therapists to monitor progress, adjust routines, and provide personalized support even when patients are at home. Figure 2.5 shows IOT in healthcare [12].

Figure 2.5: IOT in healthcare

3.0 METHODOLOGY

This project was conducted in several key phases, beginning with problem identification and ending with prototype testing. The overall methodology was designed to ensure systematic development of the hand therapy device for stroke patients.

A. Block Diagram Project

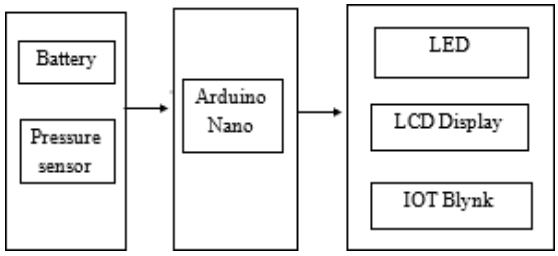


Figure 3.1: Block Diagram

Figure 3.1 presents the block diagram of the system, which outlines the overall process flow for measuring finger grip strength using a pressure sensor. The system begins with a battery as

the power source, supplying energy to all components to ensure proper device functionality. The pressure sensor serves as the input component, detecting the grip force applied by the patient's hand and converting it into an electrical signal for further processing. This signal is then sent to the Arduino Nano, which functions as the central processing unit of the system. The Arduino Nano not only gathers and interprets sensor data but also determines the corresponding output actions. It is capable of interfacing with a range of electronic components, including LEDs, motors, sensors, and actuators, and is widely used in automation and remote-control applications. Additionally, the Arduino Nano can be integrated with Wi-Fi modules to support Internet of Things (IoT) functionality, allowing the system to transmit data wirelessly through platforms like Blynk for real-time monitoring and remote access. The LEDs in the system provide immediate visual feedback. They can be programmed to illuminate based on the intensity of the grip more lights will turn on with a stronger grip. LEDs may also serve as indicators for exercise repetitions; for example, an LED can blink or change colour each time a grip is completed, helping users and therapists track the number of repetitions performed. The LCD display shows numerical or text-based information, such as grip strength levels or the count of completed exercises, offering a user-friendly interface. Together with Blynk, this setup enables both local and remote tracking of patient performance during rehabilitation sessions.

B. Flowchart Project

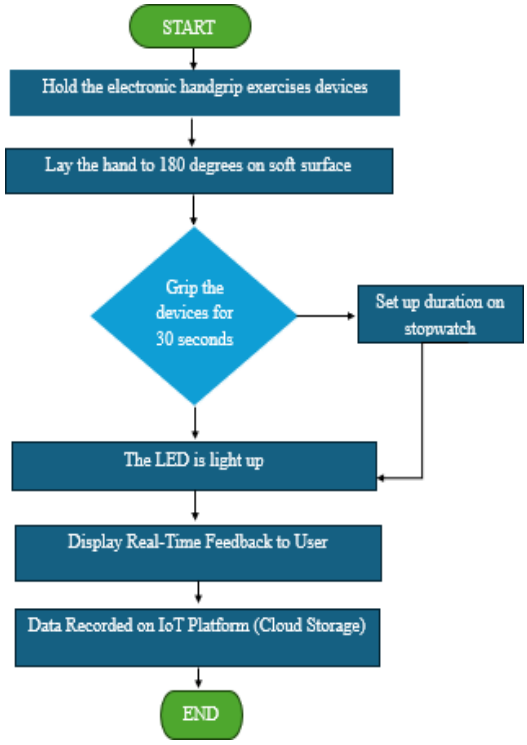


Figure 3.2: Flowchart Project

Figure 3.2 shows the flowchart for Real-Time IoT Hand Grip Exercise Technology with Pressure Sensors for Post-Stroke Rehabilitation outlines the hand rehabilitation process for stroke patients with remote monitoring and real-time feedback. Firstly, the patient should hold the handgrip exercise device to perform hand exercises. The patient's fingers should grip the handle section. Patients need to lay their hands to 180 degrees on soft surface before doing exercises. Gripping the device for 30 seconds is a structured exercise aimed at strengthening hand muscles, improving endurance, and enhancing coordination of hand movements. This exercise is typically designed for patients recovering from conditions that affect hand strength

and function. Set up duration use stopwatch while doing exercise. The LED blinks when hand pressure is felt, indicating that the grip strength is returning to normal. Real-time feedback is displayed to the user, providing immediate insights into their performance during exercises. This feedback helps users monitor their grip strength, duration, and progress throughout each session. The data will be recorded in IoT Blynk so that the patient and therapist can view progress during the exercise sessions.

4.0 RESULT

A. IoT Blynk Software

The Blynk IoT platform serves as the backbone of this innovative rehabilitation system, enabling comprehensive data collection and analysis for post-stroke hand grip recovery. As patients engage with the pressure-sensitive exercise device, sophisticated sensors continuously measure their grip strength, converting physical force into precise digital readings. These measurements are instantly processed by the system's microcontroller, which then transmits the data to Blynk's secure cloud infrastructure through wireless connectivity. Figure 4.1 show data in Blynk software.

Figure 4.1: IOT Blynk software

B. Data comparison normal and post stroke

This comparative data reveals significant differences in grip strength between normal and post-stroke conditions as measured by four force-sensitive resistors (FSRs). In healthy individuals, all four sensors register 100% output, indicating full grip capacity. However, post-stroke measurements show dramatic reductions across all sensors, with outputs falling to just 15% (FSR 1), 10% (FSR 2), and 7% (FSR 3 and 4). The data demonstrates a clear pattern of impairment, with FSR 1 showing relatively better preservation compared to the other sensors, suggesting some areas of the hand may retain more function than others after stroke. The particularly low readings from FSR 3 and 4 (both at 7%) likely indicate these corresponding hand regions experience the most severe weakness. These measurements provide valuable quantitative evidence of the stroke's impact on hand function, revealing not just an overall decrease in grip strength but also uneven impairment across different parts of the hand. Such detailed sensor data enables therapists to identify specific areas needing targeted rehabilitation and establishes precise baselines for tracking recovery progress over time. The significant disparity between normal and post-stroke measurements (ranging from 85-93% reduction) underscores the profound effect stroke can have on hand function while highlighting the potential value of sensor-based monitoring in rehabilitation programs.

Table 4.2 show comparison normal and post stroke patient.

	FSR 1	FSR 2	FSR3	FSR 4
NORMAL	100%	100%	100%	100%
POST STROKE	15%	10%	7%	7%

5.0 CONCLUSION

This project introduces an advanced rehabilitation system designed to improve hand grip recovery for stroke survivors by integrating real-time monitoring and IoT technology. The developed device utilizes pressure sensors to accurately assess grip strength while providing instantaneous visual feedback through LED indicators and an LCD interface. A key feature is its wireless connectivity to the Blynk platform, enabling remote progress tracking by healthcare professionals and patients alike. The technology addresses critical gaps in conventional rehabilitation approaches by delivering objective performance metrics, personalized exercise regimens, and convenient tele rehabilitation capabilities. Comparative analysis of grip strength data between healthy individuals and post-stroke patients reveals significant differences, demonstrating the system's diagnostic potential. By combining precise measurement tools with cloud based data management, this solution enhances treatment customization and patient motivation during recovery. The successful implementation of this prototype highlights the growing role of smart technologies in modern healthcare, particularly for neurological rehabilitation. Future developments could explore machine learning integration for predictive analytics and expanded functionality to address other motor impairments. This innovation represents a meaningful advancement in making stroke rehabilitation more accessible, measurable, and effective through technological integration.

REFFERENCES

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Reminder System for Pregnant Women with Gestational Diabetes Mellitus Using Portable Non-Invasive Blood Glucose Monitoring and Internet of Things Application

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ABSTRACT

This study addresses the challenge of managing Gestational Diabetes Mellitus (GDM) by developing a portable, non-invasive blood glucose monitoring system integrated with a smartphone-based Internet of Things (IoT) application. The main objective is to reduce discomfort from traditional invasive methods and improve monitoring compliance among pregnant women. The system uses optical sensing through a laser module and Light Dependent Resistor (LDR) to estimate blood glucose levels, while the mobile application stores data, sends reminders, and facilitates result tracking. The research method involves hardware and software development, followed by system testing and user trials. Findings show that the system achieved over 80% accuracy compared to standard glucometers and improved user compliance and satisfaction. The study concludes that combining non-invasive technology with IoT applications can enhance GDM management, reduce patient discomfort, and support better maternal and fetal health. Further research is recommended to improve accuracy, validate results across larger populations, and explore integration with clinical systems.

Keywords: Gestational Diabetes Mellitus, Non-Invasive Glucose Monitoring, Internet of Things (IoT), Laser Sensor, Pregnancy.

1.0 INTRODUCTION

Gestational Diabetes Mellitus (GDM) is a form of diabetes that develops during pregnancy, typically diagnosed in the second or third trimester [1]. It results from the body's inability to produce sufficient insulin to meet the increased metabolic demands, leading to elevated blood glucose levels. Although GDM often resolves after childbirth, it poses significant risks to both mother and baby, including preeclampsia, macrosomia, preterm birth and an increased likelihood of developing type 2 diabetes later in life [2], [3].

Blood glucose monitoring is essential for managing GDM, traditionally relying on invasive finger-prick tests to measure glucose levels. While accurate, these methods can be uncomfortable and inconvenient due to frequent pricking, potentially causing pain, irritation, or infection [4]. In managing blood glucose for insulin-dependent pregnant women, glucose checks are conducted multiple times throughout the day to ensure stable control [5]. The timeframe allows for the early identification and management of any potential glucose metabolism issues that may arise during pregnancy [3], [5].

The integration of the Internet of Things (IoT) in healthcare has introduced smart reminder systems to enhance patient adherence to treatment regimens. IoT-enabled systems leverage sensors, cloud platforms, and mobile applications to provide real-time notifications, assisting users in tasks such as glucose monitoring and medication intake [6]. These technologies have proven effective in improving adherence and reducing missed actions, particularly in chronic disease management and maternal care [7].

1.1 Limitations of Invasive Blood Glucose Monitoring During Pregnancy

Gestational Diabetes Mellitus (GDM) requires regular monitoring to prevent complications for both the mother and fetus. Invasive blood glucose monitoring is a method that typically involves obtaining blood samples through finger pricks or venepuncture to measure glucose levels directly. However, conventional blood glucose monitoring methods, which involve invasive finger-prick tests, often cause discomfort and reduce compliance among pregnant women [8], [9]. The frequency of these finger pricks can lead to anxiety or avoidance behaviour, thereby decreasing the consistency of monitoring routines.

1.2 Non-Invasive Glucose Monitoring Technologies

To solve this problem, researchers have investigated several non-invasive techniques. The ability of optical methods like near-infrared (NIR) spectroscopy and laser-based sensors to measure blood sugar levels without penetrating the skin attracts attention. Laser modules have demonstrated in detecting blood glucose by analyzing variations in light absorption through tissue [10]. These techniques are generally more acceptable to users and reduce the risks of infection and skin irritation. It categorizes the technologies based on their principles such as optics, microwave, and electrochemistry by illustrating the range of solutions being developed to make diabetes management less invasive and more user-friendly [11].

1.3 IoT Integration in Medical Devices

The integration of Internet of Things (IoT) technology into biomedical devices has enhanced remote monitoring and data management capabilities. IoT platforms enable automatic data storage, real-time monitoring and visualization through mobile applications, which is especially useful for patients who may forget or fail to manually record their glucose readings [12]. For pregnant women, these systems can support glucose monitoring and fasting schedules for ensuring better health outcomes. These systems often use features such as wearable sensors, cloud connectivity, and smartphone notifications to support chronic disease management and preventive care. Moreover, IoT systems also improve healthcare efficiency by providing automated alerts for critical conditions and facilitating immediate intervention [7].

1.4 Reminder Systems for Patient Adherence

Recent developments have also demonstrated the effectiveness of mobile-based reminder systems in improving patient adherence to treatment and testing schedules [12], [13]. These systems can be programmed to notify users of testing times and fasting periods, which is particularly beneficial for pregnant women who may experience cognitive or emotional strain. These features are especially beneficial for individuals with conditions like Gestational Diabetes Mellitus (GDM), where timing and consistency in glucose monitoring are critical. For pregnant women, the cognitive load associated with pregnancy, combined with emotional and physical stress, can often lead to forgetfulness and irregular monitoring.

2.0 METHODOLOGY

2.1 Planning of Product Development

This project aims to develop a portable, non-invasive glucose monitoring device for pregnant women with Gestational Diabetes Mellitus (GDM). The device uses a laser module and photodiode to detect blood glucose levels based on optical absorption. A microcontroller processes the signal and sends the data to a cloud platform via IoT technology. A mobile app developed using MIT App Inventor displays glucose readings and provides reminders for scheduled measurements. The system design includes a block diagram showing the flow from the sensor to cloud storage and mobile display. All components were selected based on accuracy, compatibility and user-friendliness for home use.

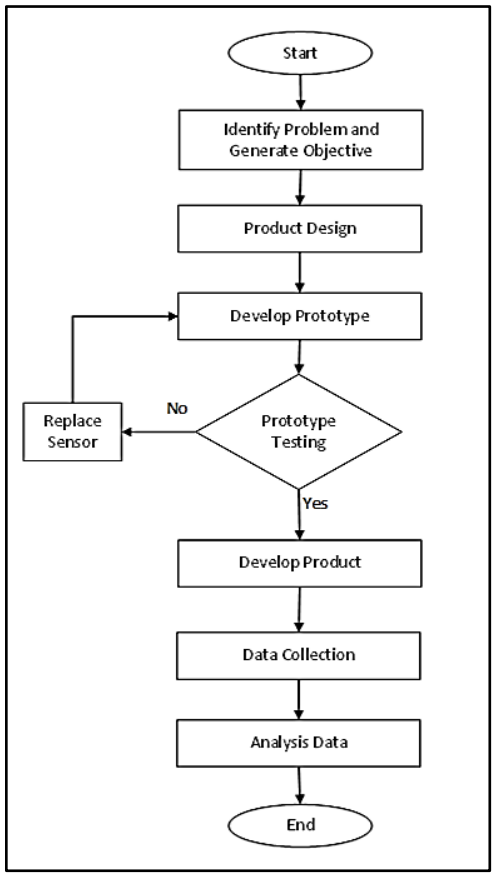

Figure 2.1: Flow Chart of Product Development

This flowchart in Figure 2.1 shows the sequential procedures involved in developing a portable, non-invasive blood glucose monitoring device. The development begins with identifying the problem and generating clear objectives, followed by designing the product based on those requirements. After that, a prototype is developed and tested. If the prototype fails, particularly due to sensor issues, the sensor is replaced, and the testing cycle repeats. When the prototype works well, the finished product is created. Following testing, data is gathered and evaluated to assess the product's usability and performance. This systematic approach ensures continuous refinement and validation, leading to a reliable and effective device.

2.2 Material and Equipment

This study develops a portable, non-invasive glucose monitor using optical absorption spectroscopy with a laser-photodiode pair, microcontroller-based signal processing and wireless data transmission. Non-invasive blood glucose monitoring hardware component:

- Laser Module: Emits light at a wavelength absorbed by glucose.
- Light Dependent Resistor Sensor: Detects reflected light intensity changes correlated with blood glucose concentration.
- ESP32 Board: Processes photodiode signals, runs calibration algorithms, and enables Wi Fi.
- OLED Display: Shows the glucose level instantly on the device.
- Charging Board: Manages safe Li-ion battery charging.
- Lithium Battery (3.7V): Powers the device for portable use.
- Switch: Power ON/OFF control for hardware.

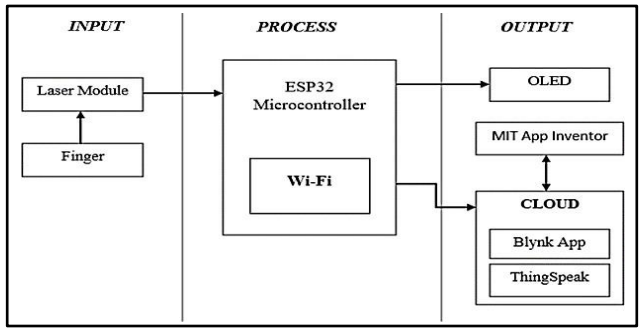

Figure 2.2: Block Diagram for Portable Non-invasive Blood Glucose Monitoring and Internet of Things Application.

Figure 2.2 illustrates a block diagram that is divided into three main sections: input, process, and output.

- Input: The user places finger near the laser module, which non-invasively detects glucose levels by emitting light that interacts with the skin. The system is powered by a 3.3V–4.2V battery controlled via a switch.
- Process: The ESP32 microcontroller receives the glucose signal from the laser sensor and processes it using algorithms programmed in the Arduino IDE. It interprets the data, calculates glucose levels, and manages Wi-Fi communication to send the processed data to cloud platforms such as Blynk.
- Output: The calculated glucose level is displayed on an OLED screen for immediate user feedback. Simultaneously, data is transmitted to the Blynk app for live smartphone monitoring and stored data. MIT App Inventor app also sends reminder notifications to encourage consistent glucose monitoring and reduce missed readings.

2.3 Software Implementation

2.3.1 Arduino IDE

The Arduino IDE was used to program the microcontroller that interfaces with the laser-based non-invasive glucose sensor. Custom firmware was developed to control the laser module, capture optical glucose data, and pre-process the signals. The Arduino code also manages wireless communication modules (Wi-Fi/Bluetooth) to transmit glucose readings to external platforms. The IDE's debugging and compilation tools ensured stable and efficient device operation, critical for real-time glucose monitoring.

3.2 Proteus 8

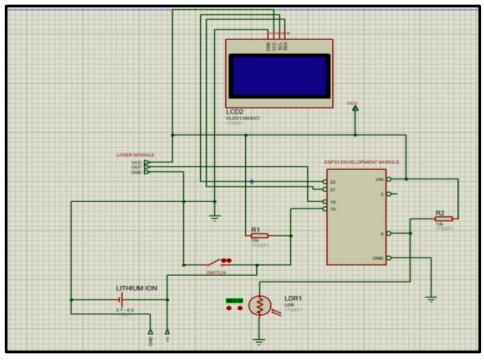

Figure 2.3.2: Circuit Diagram Using Proteus 8 Professional for Hardware Portable Non-Invasive Blood Glucose Monitoring.

Proteus 8 simulation software was employed to design and simulate the entire hardware system, including the microcontroller using ESP32, laser sensor interface, and communication modules. This allowed thorough virtual testing of sensor data acquisition and signal processing algorithms before physical prototyping, reducing development errors, and ensuring the system's reliability in measuring glucose levels non-invasively. In Figure 2.3.2 shows the circuit diagram for portable non-invasive blood glucose monitoring. The component in the circuit connected controller board (ESP32 WROOM). Laser module as transmitter and photodiode as receiver.

2.3.3 Blynk Platform

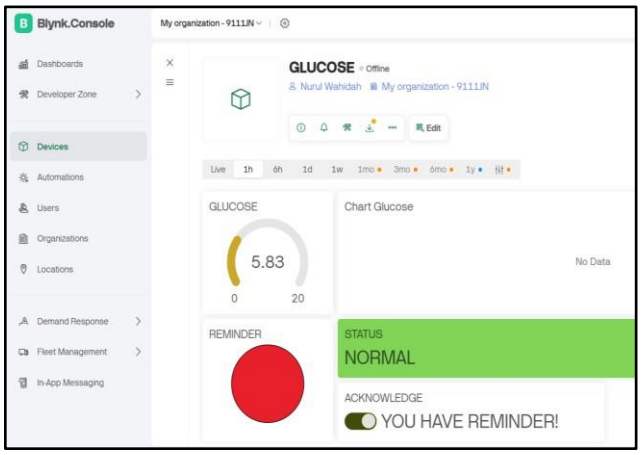

Figure 2.3.3: Blynk Layout for Glucose Monitoring

Blynk was integrated as the primary IoT platform to enable real-time remote monitoring of glucose levels via a smartphone app as shown as Figure 2.3.3. The Blynk app provides a user friendly interface displaying live glucose readings, historical trends, and automated reminders for glucose measurements or medication adherence. By connecting the Arduino device to the Blynk Cloud, patients and healthcare providers can access data anytime, improving compliance and timely intervention in GDM management.

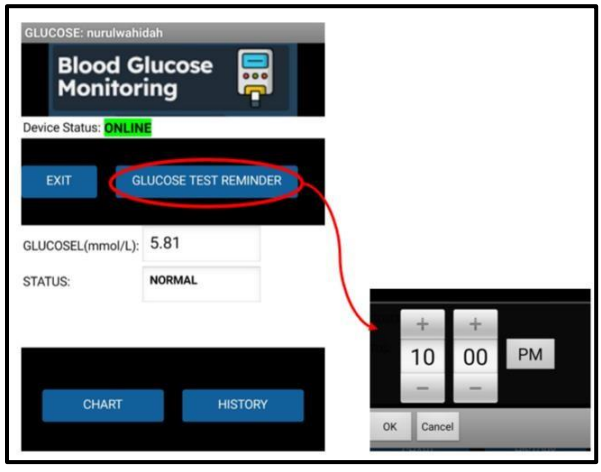

Figure 2.3.4: MIT App Inventor Interface.

2.3.4 MIT App Inventor

To complement the Blynk interface, a custom Android app was developed using MIT App Inventor. This app offers additional functionalities such as personalized reminders for glucose testing as shown in Figure 2.3.4 and doctor appointments tailored for GDM patients. The app also allows exporting glucose data and syncing with Blynk via web APIs. MIT App Inventor's visual programming environment accelerated development, enabling rapid iteration and user centric design.

2.3.5 ThingSpeak Platform

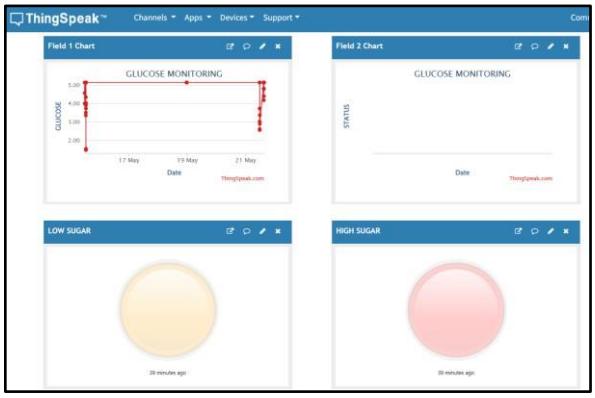

Figure 2.3.4: ThingSpeak Layout for Result of Glucose

ThingSpeak was integrated alongside Blynk to enable cloud-based storage and export of glucose data in Excel format, as shown in Figure 2.3.4. The ThingSpeak platform collects data from the ESP32 microcontroller and logs each glucose measurement in real time. This allows users and healthcare professionals to access, download, and analyze glucose trends over time using spreadsheet tools, supporting better documentation, reporting, and follow-up in GDM management. The integration with ThingSpeak enhances the system's functionality by providing a secure, accessible, and structured database for long-term monitoring and data analysis.

3.0 RESULT AND ANALYSIS

3.1 Technical Validation: Accuracy of Non- Invasive Glucose Monitoring System Table

Table 3.1: Comparison of Non-Invasive and Invasive Glucose Readings for Accuracy Validation

Calculation for Mean Absolute Relative Difference (MARD)

$$MARD(\%) = \frac{Total\ Error\ (\%)}{Total\ numb\ of\ Sample}$$

$$MARD(\%) = \frac{19.15 + 17.95 + 17.14 + 20.75 + 19.70 + 18.00 + 21.43 + 18.42 + 18.33 + 21.82}{10}$$

$$= 19.269\%$$

Test Sample	Invasive Glucose Meter Reading (mmol/L)	Non- Invasive Device Reading (mmol/L)	Error (%)
1	4.7	3.8	19.15
2	3.9	3.2	17.95
3	3.5	2.9	17.14
4	5.3	4.2	20.75
5	6.6	5.3	19.70
6	5	4.1	18.00
7	4.2	3.3	21.43
8	3.8	3.1	18.42
9	6	4.9	18.33
10	5.5	4.3	21.82
Total Error (%)			192.69

Table 3.1 shows the accuracy assessment of the non-invasive glucose monitoring device tested against a standard invasive glucometer under controlled conditions. The Mean Absolute Relative Difference (MARD) was used to evaluate the device's performance. The average error percentage was found to be 19.27%, which indicates moderate accuracy and highlights the need for further calibration and improvement for clinical reliability.

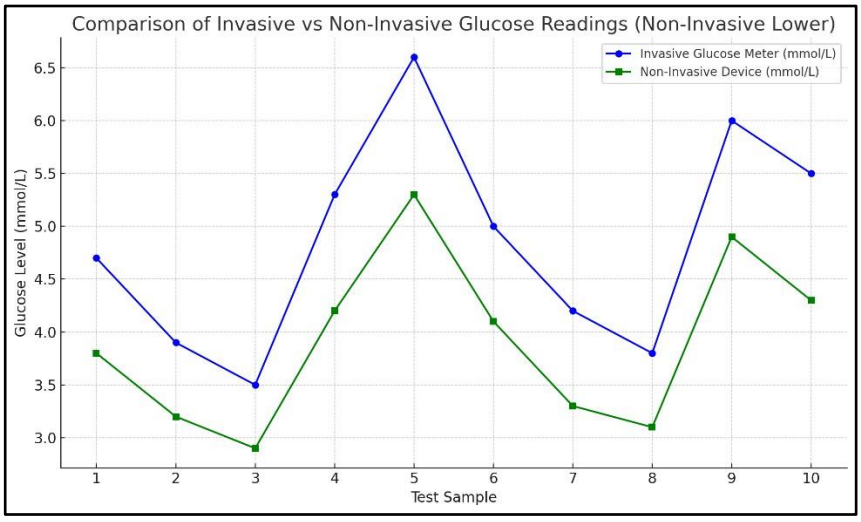

Figure 3.1: Comparison of Invasive vs Non-Invasive Glucose Readings

The Figure 3.1 shows the compares glucose levels measured by a conventional invasive glucometer and the non-invasive device developed in this project. The results from 10 test samples show that the non-invasive readings (green line) are consistently lower than the invasive readings (blue line), as expected. Despite the difference, the non-invasive device shows a consistent pattern and achieves approximately 80% accuracy, making it suitable for monitoring trends in glucose levels for pregnant women with GDM.

3.2 System Performance and App Usage Analysis

App usage logs from 5 participants were analyzed over a 1-week period to quantify the impact of IoT-enabled reminders on glycaemic monitoring behaviour.

Table 3.2: Compliance Metrics Before vs. After IoT System Deployment

Parameter	Before Using IoT System (%)	After Using IoT System (%)
Missed glucose readings	39	5
Delayed readings (>15 min)	65	10
Properly logged data	60	93

Table 3.2 shows the compliance metrics compared before and after the implementation of the Internet of Things (IoT) system, revealing three significant improvements. Firstly, missed glucose readings dropped from 39% to 5%, indicating a substantial increase in adherence to scheduled measurements. Secondly, delayed readings (more than 15 minutes late) decreased from 65% to 10%, showing improved timeliness in glucose monitoring. Lastly, properly logged data increased from 60% to 93% due to automated cloud-based recording, significantly reducing manual entry errors common with traditional logbooks.

4.0 CONCLUSION

In conclusion, this project successfully designed and developed an IoT-based Reminder System for Gestational Diabetes Management using Non-Invasive Glucose Monitoring. The system integrates a laser module and Light Dependent Resistor (LDR) for painless glucose detection, an ESP32 microcontroller for data processing and cloud connectivity, and a mobile application developed with MIT App Inventor to deliver reminders and display glucose data.

By combining non-invasive sensing with Internet of Things (IoT) features, the system effectively enhanced glucose monitoring practices among pregnant women with Gestational Diabetes Mellitus (GDM). Real-time data visualization via Blynk and automated data export through ThingSpeak allow both users and healthcare providers to monitor glucose trends efficiently. Reminder notifications significantly improved compliance, as shown by the reduction in missed readings from 39% to 5%, delayed readings from 65% to 10%, and an increase in properly logged data from 60% to 93%.

Usability testing with 10 pregnant women showed high satisfaction participants found the system easy to use, comfortable, and responsive to scheduled alerts. In terms of technical performance, the system achieved a Mean Absolute Relative Difference (MARD) of 19.256% when compared to standard glucometers, indicating moderate accuracy and the need for further calibration.

Overall, the project met its objectives and offers a promising, user-friendly solution to support GDM management. Future improvements should focus on enhancing sensor accuracy, expanding clinical trials, and upgrading app features to include healthcare provider integration, trend analysis, and multi-user capability.

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Sensor-Based Rehabilitation Glove with Real-Time Monitoring for Stroke Patients

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ABSTRACT

This study focuses on the development of a sensor-based rehabilitation glove with real-time monitoring to support stroke patients in their recovery. Traditional rehabilitation methods often lack continuous feedback and real-time progress tracking, which are critical for effective therapy. By integrating low cost flex and gyroscope sensors, this glove captures hand movements and transmits the data via Blynk IoT platform to a mobile application developed using MIT App Inventor, providing immediate feedback to both patients and therapists. The project leverages wearable technology and IoT to enable personalized and accessible home-based rehabilitation. The results aim to enhance recovery outcomes, improve patient engagement, and empower therapists with accurate, real-time data for adaptive treatment strategies.

Keywords: Rehabilitation glove, stroke therapy, flex sensor, gyroscope, ESP32, MIT App Inventor.

1.0 INTRODUCTION

Stroke is considered one of the leading contributors to disabilities, especially those that require motor functions, hand function included, which affects millions across the globe. Most of the available modalities for rehabilitation do not offer individual feedback and do not keep records of patient progress on a real-time basis, which usually hinders the healing process and demoralizes the patients as well[3],[6]. Modern rehabilitation gloves have been beneficial across many spheres, most notably the advancement in wearable technology. The gloves are beneficial in that their technology allows for monitoring of the patient's progress and therapy in a customized way and in between clinic visits. The gloves have flex and gyro sensors that detect hand movements and provide instant feedback, allowing patients to do rehabilitation activities at home more easily and effectively [1].

Recent studies have shown that rehabilitation for stroke patients using gloves equipped with built-in sensors has a significant positive impact on restoring motor functions [4],[5]. These smart gloves provide personalized exercises with real-time monitoring and feedback, making them an effective tool for rehabilitation. As highlighted by Nawi et al. [2], this type of wearable technology integrates not only flex sensors but also gyroscopic sensors to track hand movements, thereby enhancing the rehabilitation process and accelerating recovery. Additionally, the integration of a mobile application capable of displaying real-time progress enables continuous follow-up, allowing healthcare providers to adapt interventions based on the gathered data. Thus, studies on mobile applications for healthcare monitoring whether for rehabilitation or general health highlight their effectiveness in improving patient outcomes and enabling remote supervision. These apps offer features like real-time data tracking, personalized feedback, and long-term progress monitoring [3],[6].

The objective of this research is to design and assess a Sensor-Based Rehabilitation Glove With Real- Time Monitoring For Stroke Patients aimed at aiding stroke patients in their recovery. The glove will utilize flex and gyro sensors to monitor hand movements and track progress via

a mobile application.
This study's findings aim to enhance existing stroke rehabilitation techniques by making the process more efficient, engaging, and accessible for patients.

2.0METHODOLOGY

2.1Project Idea

This study explains the creation and testing of the glove designed to assist stroke patients. The glove was carefully developed with specialized sensors to track finger movements and hand position [4],[5]. Data from these sensors is transmitted to an app, where it is displayed in real-time, enabling the monitoring and analysis of patients' hand movement progress [7]. The design and testing process ensure the glove provides accurate information to support rehabilitation.

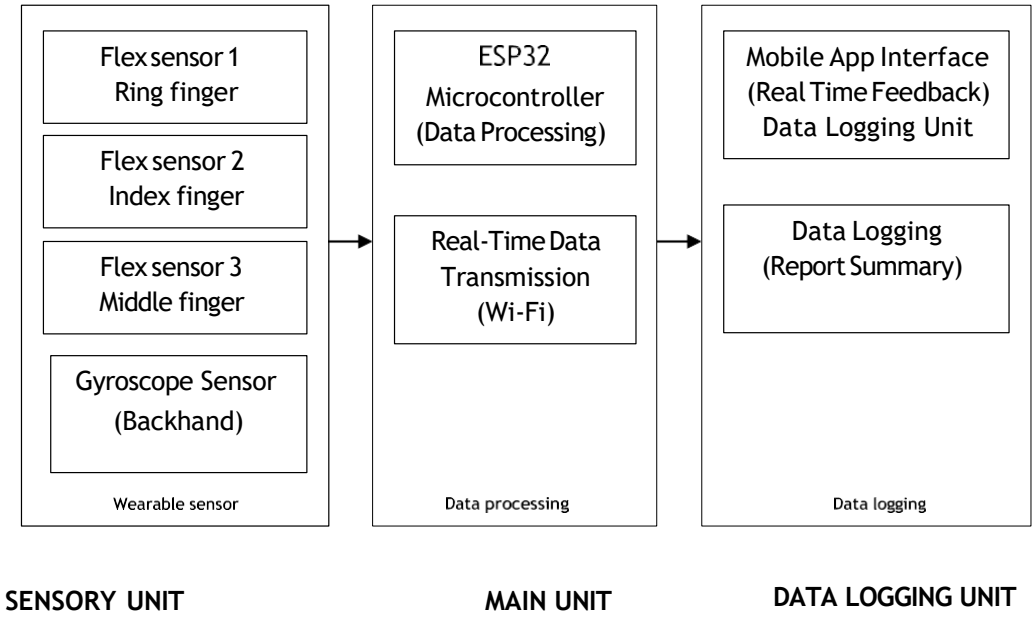

Figure 1. Block diagram for Hand Rehab Glove of Design

The block diagram in Figure 1 illustrates a sensor-based rehabilitation system designed to monitor wrist and finger movements, process real-time data, and provide user feedback. Flex sensors are strategically placed on the index, ring, and thumb fingers to measure bending angles during hand exercises. These sensors detect changes in resistance as the fingers bend, capturing the degree of flexion and movement. Meanwhile, a gyroscope sensor is placed on the back of the hand to measure angular velocity and wrist orientation, enabling precise tracking of rotational movements such as flexion, extension, and deviation [10].

The data collected from the sensors is processed using an ESP32 microcontroller, which serves as the central processing unit. The ESP32 transmits the real-time data wirelessly via Wi-Fi to a mobile application. The mobile app displays the processed sensor data in a user-friendly interface, providing immediate feedback on hand and wrist performance [8]. Finally, users receive visual feedback through graphs or charts, showcasing both flex sensor and gyroscope sensor data, which helps monitor progress and enhance the effectiveness of rehabilitation exercises[9].

2.2 Sensor Based Rehab Glove

Figure 2. Illustration Of The Glove Employed In This Study [1]

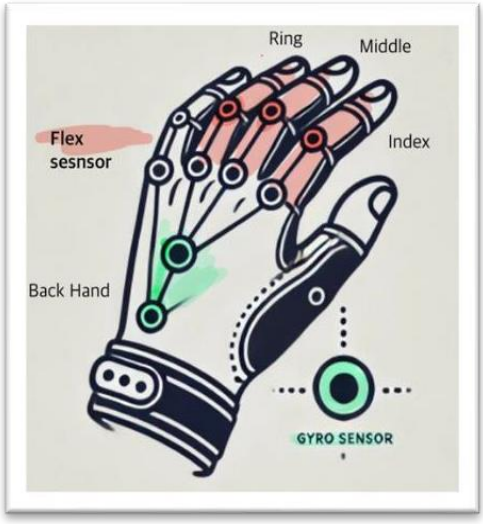

Figure 3. Illustration Of The Sensor Placement On The Glove [2]

The glove shown in Figure 2 [1] used in this study is made of flexible and breathable fabric, ensuring comfort during extended use while still providing support for the hand. Flex sensors are strategically placed on the index, ring, and middle fingers to measure bending angles during hand exercises (Figure 2). These sensors detect changes in resistance as the fingers bend, capturing the degree of flexion and movement. The placement of these sensors on the specified fingers is based on [7],[10], as these fingers are key in performing various rehabilitation exercises.

Meanwhile, a gyroscope sensor is placed on the back of the hand to measure angular velocity and wrist orientation, enabling precise tracking of rotational movements such as flexion, extension, and deviation. An example of wrist movement tracking can be seen in Figure 3 [2].

2.3 Internet of Things (IoT) Application Development – MIT App Inventor

Figure 4. MIT App Inventor

The use of an MIT App Inventor-based application, as illustrated in Figure 4, in the study of a sensor- based rehabilitation glove for stroke patients is crucial for tracking rehabilitation progress. MIT App Inventor is a user-friendly platform for developing mobile applications, allowing data visualization from the glove's sensors. This application enables both patients and healthcare providers to monitor hand movements and track rehabilitation sessions. By integrating the glove with cloud services, patient performance data is stored for long-term tracking, making it easier to assess progress and adjust therapy as needed. The app developed with MIT App Inventor is compatible with Android devices, ensuring accessibility and ease of use. Its integration with the IoT-based glove system improves patient engagement and recovery by providing feedback and encouraging consistent rehabilitation exercises. Studies have shown that app-based monitoring helps improve patient outcomes by maintaining motivation and offering regular progress updates [8],[9].

2.4 Internet of Things (IoT) Data Transmission – Blynk Platform

Figure 5 : Blynk Platform

The Blynk platform is used in this project to enable real-time data transmission between the rehabilitation glove and the mobile application. Blynk allows the ESP32 microcontroller to send sensor data such as finger bending (from flex sensors) and wrist movement (from the gyroscope) directly to a smartphone via the internet. With Blynk, the data is displayed on a customizable dashboard in the app, giving patients and therapists immediate feedback during rehabilitation exercises [11]. This helps ensure the exercises are done correctly and allows for continuous monitoring without the need for in-person supervision. Blynk also supports cloud storage, which helps in recording session history, tracking progress over time, and making informed therapy adjustments. Its compatibility with Android, along with a simple drag-and-drop interface, makes it ideal for IoT-based health applications like this smart rehab glove.

3.0 RESULTS AND DISCUSSION

The smart rehabilitation glove developed in this project effectively recorded finger flexion and wrist orientation by utilizing integrated flex sensors and a gyroscope, ensuring consistent and accurate data throughout each rehabilitation session. Designed with user comfort in mind, the glove proved suitable for repeated hand exercises, particularly for stroked patients undergoing therapy. Moreover, the system's mobile application, built using MIT App Inventor and connected via the Blynk IoT platform, provided real-time monitoring with minimal delay. All exercise data was automatically saved in Rehab Sync Apps, providing a centralized and accessible location for tracking rehabilitation progress. Additionally, the data can be exported or shared through platforms such as Google Drive, Telegram, WhatsApp or email, allowing patients and therapists to conveniently store, review, and exchange session records for ongoing monitoring and feedback. This seamless integration of hardware and software enabled a more engaging and accessible home-based rehabilitation experience.

3.1Hand Rehabilitation Glove

The results show consistent data acquisition by the glove sensors and reliable wireless data transmission to the mobile application. Figure 6 shows the hand rehabilitation glove used in the study. Figure 7 displays the flex sensor readings during finger movements and the gyroscope sensor readings, indicating wrist orientation throughout the rehabilitation session.

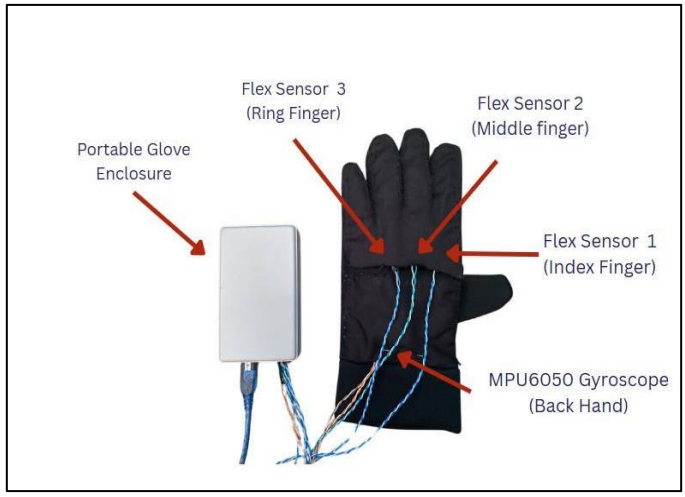

Figure 6 : Hand Rehabilitation Glove

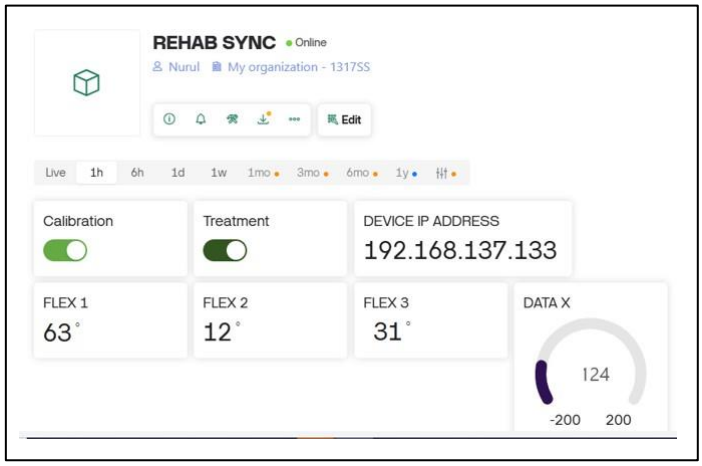

Figure 7 : Reading of Flex and Gyro Sensor

The results in Figure 6 showed that the flex sensors effectively detected changes in finger positions, with clear variations during hand movements, indicating their responsiveness to bending actions. Similarly, the gyroscope sensor successfully captured wrist orientation along the X-axis, as displayed in the Blynk Dashboard platform. The sensor data was transmitted to the mobile application in real time, confirming the system's capability to monitor hand and wrist movements accurately for rehabilitation purposes. Key parameters measured included finger position, detected through resistance changes in the flex sensors (measured in degrees), and wrist orientation, measured via gyroscope angular velocity on the X-axis (measured in degrees per second). Real-time data transmission was also evaluated based on refresh rate and signal stability, ensuring reliable tracking during rehabilitation sessions.

3.2App Monitoring System – Rehab Sync

The app monitoring system was developed using MIT App Inventor in combination with the Blynk IoT platform, serving as the main interface for both patients and therapists. It connects wirelessly to the glove via Wi-Fi and displays real-time data from the flex and gyroscope sensors. The app shows live feedback of finger bending and wrist movement, helping users understand their hand performance during rehabilitation exercises. All session data is automatically saved into the Rehab Sync app, where it can be accessed for long-term tracking and analysis.

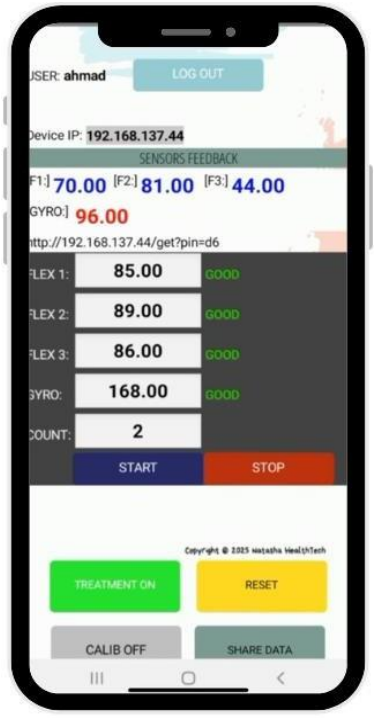

Figure 8. App Monitoring System

Figure 8 shows readings for the index finger, middle finger, and gyroscope orientation consistently showed values above 70, indicating good sensor response during trials with normal individuals. The user interface was designed to be simple and clear, making it easy for both patients and students to navigate and use during daily rehabilitation sessions. This system supports remote monitoring, allowing therapists to follow patient progress and adjust therapy as needed.

4.0 CONCLUSION

The development of the Sensor-Based Rehabilitation Glove with Real-Time Monitoring for Stroke Patients has demonstrated significant potential in supporting post-stroke hand therapy. By integrating flex sensors and a gyroscope with an ESP32 microcontroller, the system successfully captured hand and wrist movements, allowing for real-time data processing and wireless transmission to a Flutter- based mobile application. This setup not only enabled real-time feedback but also facilitated the storage and analysis of patient progress over time. The glove allows patients to conduct rehabilitation exercises independently while providing therapists with access to accurate data for remote monitoring.

The usability tests with healthy participants showed consistent performance in step counts and movement tracking, indicating that the glove can reliably capture motion data. These findings reinforce the system's reliability and practicality as a cost-effective rehabilitation tool.In conclusion, this study offers a promising solution for enhancing stroke rehabilitation by combining wearable sensor technology with mobile health applications. Future work should focus on clinical trials with stroke patients, improving user interface design, and exploring machine learning integration for predictive recovery analysis.

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Wearable IoT-Based Device for Parkinson's Symptoms Detection Using Tremor and Hand Strength Sensors

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ABSTRACT

The increasing prevalence of Parkinson's disease (PD), especially among aging populations, underscores the need for accessible and continuous monitoring solutions for early symptom detection. Current diagnostic methods, such as clinical evaluations, are often episodic and may miss early-stage motor symptoms, leading to delayed diagnosis. This paper presents a wearable IoT-based attachment designed to detect Parkinson's symptoms in real-time, focusing on hand tremors and hand muscle strength. The system employs piezoelectric sensors to detect tremors during activities like finger tapping, hand fist closure, and resting tremor, capturing key parameters such as frequency, amplitude, and waveform patterns. Force-sensitive resistors (FSR) are integrated to assess hand muscle strength, providing a comprehensive evaluation of motor function. The sensors are embedded in an attachment and connected to an Arduino Nano V3 microcontroller, which processes and transmits data to an IoT platform for real-time visualization. The device is being developed to collect movement-related data, aiming to offer insights into Parkinson's symptoms outside clinical settings. By enabling real-time monitoring and early detection, the system facilitates timely intervention, potentially slowing disease progression. This affordable, user-friendly solution bridges the gap between clinical assessments and daily symptom tracking, enhancing accessibility to continuous health monitoring and improving disease management.

Keywords: Parkinson's symptom, wearable technology, IoT-based monitoring, hand tremor detection, hand strength assessment

1.0 INTRODUCTION

Millions of people worldwide suffer with Parkinson's disease (PD), a degenerative neurological condition that mostly affects movement. Recent data indicates that 0.2% of Malaysians have been diagnosed with Parkinson's disease; as the population ages, this percentage is predicted to increase (Milad Hassandarvish, 2019), (Tysnes & Storstein, 2017). Numerous motor symptoms, including as tremors, stiffness, delayed movement, and balance issues, are symptomatic of the condition. These symptoms have the potential to dramatically diminish a person's quality of life as the illness progresses, making routine chores more difficult and increasing their need on caretakers.

Early diagnosis and intervention are critical for good Parkinson's disease management. According to research, early detection of the disease can help halt its course and improve patient outcomes (Ab Hamid et al., 2023). Unfortunately, existing diagnostic techniques and methods are primarily based on episodic assessments undertaken in clinical environments. Electromyography (EMG) and tremor analysis are two traditional approaches used to examine symptoms during clinic visits. While these approaches are beneficial for diagnosing Parkinson's disease in its late stages, they fall short in distinguishing moderate early-stage symptoms, particularly when they occur rarely outside of a clinical context. As a result, patients typically experience diagnostic and treatment delays, which can lead to more significant health consequences and complications.

Access to healthcare services in Malaysia is sometimes limited, particularly among rural communities. Many people struggle to make regular trips to healthcare facilities for examinations. This gap in care is worsened by the fact that standard diagnostic procedures do not allow for continuous monitoring at home, which is required to capture the intermittent character of early symptoms. As a result, there is an urgent need for novel solutions that can aid in the early diagnosis of Parkinson's disease while accommodating the problems that patients encounter (Kehnemouyi et al., 2024).

1.1 Parkinson's Illness Overview

Parkinson's disease (PD) is a progressive neurodegenerative disorder primarily affecting the motor system. It results from the degeneration of dopaminergic neurons in the substantia nigra, leading to characteristic motor symptoms such as bradykinesia, tremors, and muscle rigidity. *Figure 1* below shows the affected areas of the brain in Parkinson's disease, which play a critical role in motor function and coordination (Moreau et al., 2023).

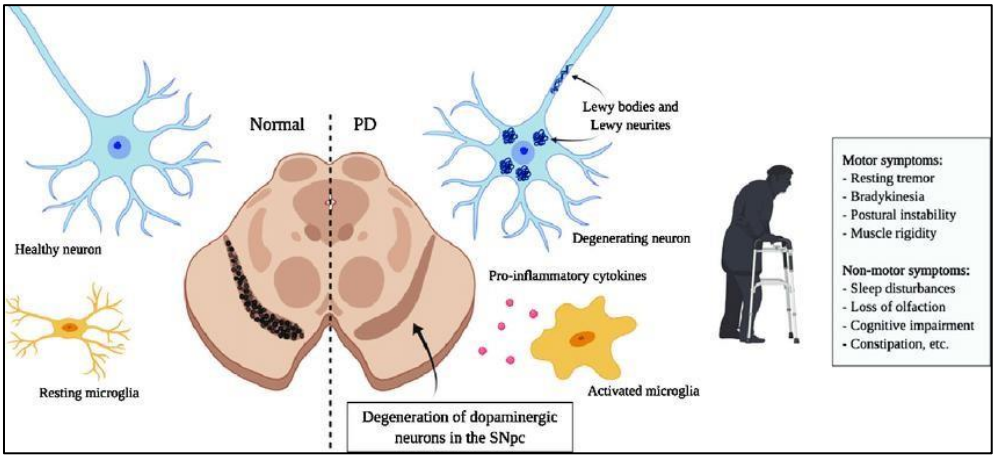

Figure 1: The Degeneration of Dopaminergic Neurons in Parkinson's Disease (Moreau et al., 2023).

As the disease progresses, non-motor symptoms such as sleep disturbances, cognitive decline, and autonomic dysfunction also emerge, further complicating management. The progression of symptoms is often slow, and patients may experience a gradual increase in severity. Early detection and consistent monitoring are critical for improving patient outcomes by enabling timely intervention. An increasingly common neurological disease that primarily affects older persons is Parkinson's disease (PD). Among the main clinical characteristics of Parkinson's disease are bradykinesia, muscle rigidity, and tremor. Thus, the diagnosis of Parkinson's disease (PD) can be facilitated by early, accurate, and convenient symptom detection, according to current research on the disease. The advancement of microelectronic and sensor technologies has greatly facilitated the early identification of Parkinson's disease by enabling the monitoring of the nearly undetectable tremor with only one hand detection (Yang et al., 2021).

1.2 Hand Motion and Neurological Disorders

Hand tremors are among the earliest and most recognizable symptoms of Parkinson's Disease (PD), typically appearing as resting tremors with frequencies ranging between 3 to 7 Hz, and occasionally as postural tremors within the 5 to 12 Hz range. These involuntary, rhythmic movements often precede other motor symptoms and are observed in about 75% of patients with PD (Rovini et al., 2017). Detecting these tremors plays a crucial role in early diagnosis and intervention. They are best captured through vibrational analysis using inertial sensors such as accelerometers and gyroscopes, which convert mechanical hand movement into digital

signals for further analysis. The progression of PD significantly impacts hand motion, where involuntary movements intensify due to dopamine loss in the brain's motor control regions. This leads to complications such as bradykinesia, muscle rigidity, and difficulties in performing daily tasks like writing or gripping objects. Advancements in sensor technologies, particularly inertial measurement units (IMUs), have improved the accuracy of tremor detection (Ravichandran et al., 2023). These IMUs allow real-time tracking of tremor characteristics, including frequency, amplitude, and motion direction. As a result, wearable solutions based on these technologies enable continuous, non-invasive monitoring, offering valuable clinical insight into disease progression and aiding personalized treatment strategies (Lu et al., 2020).

1.3 The Role of Wearable Devices in Parkinson's Disease Management

Recent development at (Kazi et al., 2021) focuses on using smart gloves equipped with piezoelectric sensors for tremor detection, showcasing the potential of wearable devices for continuous Parkinson's disease (PD) monitoring. Other efforts, such as wearable rings with embedded motion sensors (Yang et al., 2021) and multi-sensor systems combining accelerometers and gyroscopes (Moreau et al., 2020), further expand IoT-enabled solutions for tracking motor symptoms. The ITEX glove by Ravichandran et al. (2022) exemplifies remote monitoring, providing clinicians with real-time objective data for treatment adjustments. However, existing systems mainly concentrate on tremor detection, often neglecting other critical symptoms like grip strength and bradykinesia. The proposed diagnostic glove in this study seeks to overcome these limitations by integrating piezoelectric sensors for sensitive tremor detection, force-sensitive resistors (FSRs) to measure grip strength, and motion tracking capabilities to assess bradykinesia. This comprehensive monitoring strategy enhances continuous tracking of PD symptoms beyond clinical settings while ensuring patient comfort. With wireless IoT connectivity enabling real-time data transmission, the system reduces dependency on hospital visits and allows timely interventions. By offering a broader view of motor symptom progression, this approach significantly improves upon existing single symptom monitoring devices, particularly for patients in remote areas or with limited mobility (Mughal et al., 2021).

1.4 Real-Time Monitoring

Real-time monitoring is essential for effective Parkinson's Disease management, as traditional tools like the MDS-UPDRS only provide episodic insights during clinical visits. IoT-enabled wearable systems allow for continuous tracking of symptoms in daily life, improving early detection and treatment adjustment. For example, the mPower study demonstrated the feasibility of smartphone-based PD monitoring but was limited by the lack of dedicated sensors for tremor and rigidity, and by being restricted to iPhone users. In contrast, the proposed wearable device integrates piezoelectric sensors and FSRs, connected via Arduino Nano and ESP32 microcontroller, to measure hand tremors and muscle strength with higher precision and accessibility. Compared to earlier systems like the MOXS wearable, which struggled with detecting fine hand tremors and required manual symptom reporting, this design offers automatic data capture, compact form, and increased comfort. The ESP32's Bluetooth and Wi Fi capabilities allow real-time data transmission through platforms like Blynk, enabling a responsive mobile interface (Adams et al., 2021). It also supports offline data storage for later synchronization. The device is designed to complement clinical tools by correlating sensor data with the Hoehn and Yahr (H&Y) staging system. This enables objective detection of stage specific symptoms, such as unilateral tremors (Stage 1), strength asymmetry (Stage 2), fine motor decline (Stage 3), and advanced motor deterioration (Stages 4 and 5). Overall, this system offers a practical, user-friendly approach for continuous home-based monitoring, supporting more informed clinical decisions and personalized care (Y. J. Zhao et al., 2011).

1.5 Previous Study

1.5.1 Smart Ring for Tremor Detection

Yang et al. designed a smart wearable ring equipped with an MPU6050 sensor, which integrates a 3-axis accelerometer and gyroscope, to detect hand tremors in PD patients (Yang et al., 2021). The device collects finger movement data, analyzes tremor signals, and transmits the information in real time via Bluetooth Low Energy (BLE) to a smartphone application. The system successfully distinguished tremor patterns in static, walking, and simulated tremor states, demonstrating high accuracy in early PD detection. However, the device focuses solely on tremor monitoring and lacks integration with other PD symptoms, such as muscle rigidity or bradykinesia.

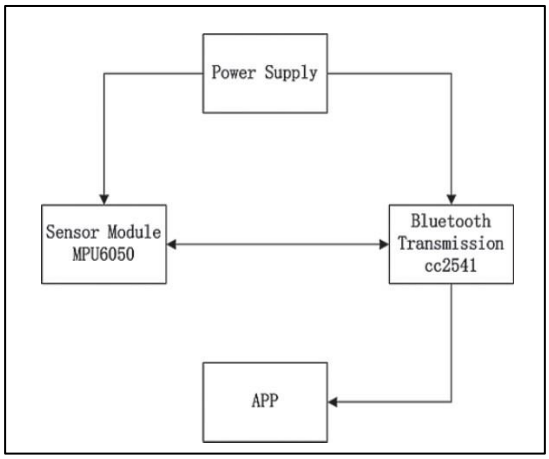

Figure 2: Hardware architecture of the smart ring system, showing data flow from the MPU6050 IMU sensor to the Bluetooth module and mobile application (Yang et al., 2021).

1.5.2 Wrist Sensor-Based Tremor Quantification Using CNN

Kim et al. proposed a wrist-worn device (SNUMAP) with an accelerometer and gyroscope to quantify tremor severity in PD patients (Kim et al., 2018). The system employs a convolutional neural network (CNN) to classify tremor severity based on Unified Parkinson's Disease Rating Scale (UPDRS) scores. By transforming sensor data into 2D frequency-domain images, the CNN achieved high accuracy (85%) in distinguishing tremor levels. While this approach advances automated tremor assessment, it is limited to wrist placement and does not address other PD motor symptoms or provide real-time feedback for patients.

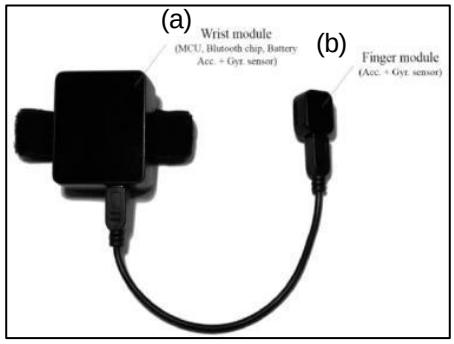

Figure 3: Custom SNUMAP wearable: (a) Wrist-worn module with IMU sensors, (b) Finger attachment for multi-position tremor analysis (Kim et al., 2018).

1.5.3 Stretchable Triboelectric Sensor for Forearm Muscle Measurement The study by Vera Anaya and Yuce (2020) introduced a stretchable triboelectric nanogenerator (TENG) sensor designed to monitor forearm muscle movements and finger motions in Parkinson's disease (PD) patients. The sensor, made of Ecoflex™ and an aluminum electrode, detects muscle contractions and tendon movements associated with hand and finger actions, such as finger tapping, pronation-supination, and tremors (Vera Anaya & Yuce, 2021). The device generates voltage signals corresponding to movement patterns, which are then classified using the MDS-UPDRS scale to assess symptom severity. Key advantages include its flexibility, comfort, and ability to indirectly measure finger motions without placing sensors directly on the hand, improving long-term wear ability. However, the system requires further validation with real PD patients and integration with real-time monitoring platforms for clinical use.

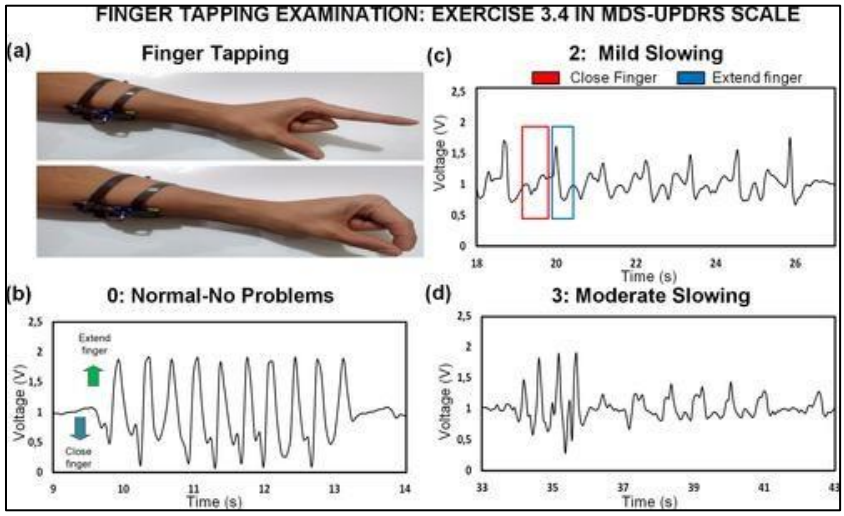

Figure 4: Voltage signal patterns corresponding to MDS-UPDRS severity levels during (a) hand opening/closing and (b) pronation-supination movements. Signal characteristics differentiate between normal (0), slight (1), and moderate (3) symptom severity. Adapted from (Vera Anaya & Yuce, 2021).

1.5.4 Handgrip Strength and Electromyography in PD

Jones et al. (2016) explored the relationship between handgrip strength and long-term electromyography (EMG) in PD patients. The study found that grip strength strongly correlates with muscle activity patterns in both upper and lower limbs, making it a potential biomarker for early functional decline. Unlike healthy controls, whose muscle activity was best explained by gait metrics, PD patients exhibited unique adaptations in muscle activation detectable through grip strength measurements. While EMG provides detailed insights into muscle function, its clinical application is limited by complexity and cost. The study highlights grip strength as a simpler, accessible alternative for monitoring PD progression (Jones et al., 2017).

Table 1: Comparative demographic and clinical characteristics of PD patients vs. healthy controls, highlighting reduced grip strength in PD.

Descriptive	PD	Control	*p*
Number female/male	12/11	8/6	
Age (years)*	66 ± 8.6	66 ± 10.6	0.89
BMI	24.5 ± 3.8	24.3 ± 3.7	0.85
PD duration (years)	8 ± 5.9	0	0.00
Hoehn Yahr	2.0 (1 - 3)	0	0.00
PD affected side (R/L)	12/11	0	0.00
Daily levo-carb dose (mg)	671.7 ± 446.9	0	0.00
Number medications	1.4 ± 1.8	0.8 ± 1.0	0.30
Number comorbidities	2.9 ± 1.8	1.2 ± 1.2	0.02
Daily step count (number)	3298.2 ± 2642.2	5017.7 ± 3382.4	0.11
EMG Recording Time (hrs)	6.2 ± 1.1	6.6 ± 0.3	0.35
Berg Balance Score	22.6 (14 - 28)	27 (24 – 28)	0.00
Dynamic Gait Score	8.0 (3 - 12)	11.75 (9 – 12)	0.00
Self-selected gait speed (m/s)	1.16 (0.75 - 1.40)	0.92 (0.85 – 1.07)	0.00
Grip strength (kg)	M 38.9 (21 - 48)	M 47.4 (40 – 55)	0.02
	F 24.6 (19 - 31)	F 33.3 (27 – 55)	

n, male; n, female; BMI, body mass index; kg, kilogram; R, right; L, left; mg, milligram levodopa component; m, meters; hrs, hours; p, significance.
*all variables are listed as mean ± standard deviation or mean (min - max). p >0.05

Source: (Jones et al., 2017).

2.0 METHODOLOGY

This project follows a systematic approach that includes the block diagram, flowchart and component selection. The wearable IoT-based device is designed to detect Parkinson's symptoms by monitoring hand tremors and hand muscle strength. Two piezoelectric sensors are used to detect tremors, while three FSR sensors on the thumb, index/middle, and middle/pinky fingers measure hand muscle strength. The Arduino Nano collects and processes the data, and the ESP32 provides wireless connectivity. Sensor data is sent to the Blynk IoT platform for real-time monitoring on a phone or laptop. The prototype is tested on both healthy individuals and those with Parkinson's symptoms to observe differences between normal hand movement and tremor vibrations.

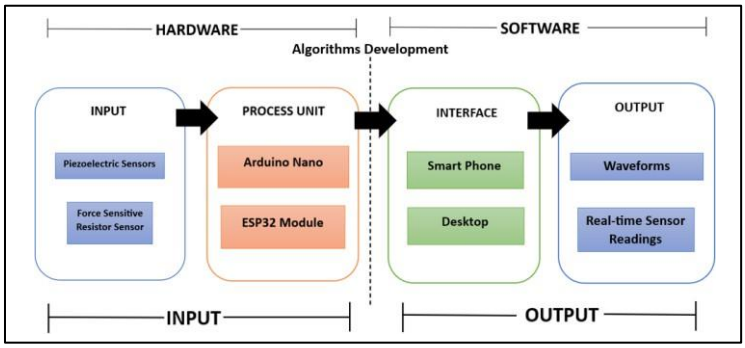

Figure 5: Framework of the project

Figure 5 illustrates the system design framework of the project 'Wearable IoT-Based Device for Parkinson's Symptoms Detection Using Tremor and Hand Strength Sensors'. The system consists of hardware and software components, which are connected through programmed

algorithms. Piezoelectric sensors are used to detect hand tremors, while force-sensitive resistor (FSR) sensors measure muscle strength. The Arduino Nano and ESP32 module function as data collectors and processors. The collected data is transmitted to a smartphone or desktop, where the software component displays real-time waveforms and sensor readings using the Blynk IoT platform.

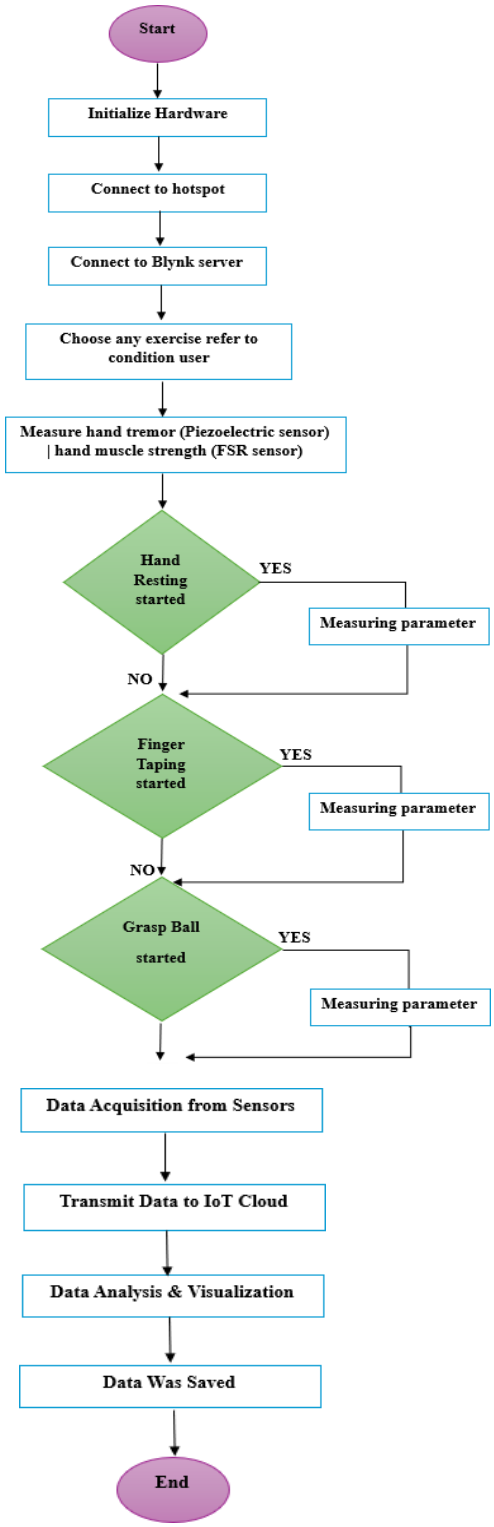

Figure 6: Flowchart of Wearable IoT-Based Device for Parkinson's Symptoms Detection Using Hand Tremor and Hand Strength Sensors (*WiPark-Sense)*

Figure 6 presents the operational flow of the wearable IoT-based device designed for Parkinson's symptoms detection. The process begins with hardware initialization, including the microcontroller, piezoelectric sensor, force-sensitive resistors (FSRs), and network modules. The device connects to the Blynk server via a mobile hotspot for real-time monitoring. Upon establishing the connection, the user selects one of three predefined motor tasks — Hand Resting, Finger Tapping, or Grasping a Ball — each targeting specific motor functions. Sensor data is collected accordingly: tremor data via the piezoelectric sensor during rest and tapping tasks, and muscle strength via FSRs during tapping and grasping. Once the activity is completed, the system acquires raw sensor data and transmits it wirelessly to the Blynk cloud. The platform then processes and visualizes the data in real time, enabling graphical and numerical analysis of motor performance. Finally, the data is stored either in the cloud or locally, supporting longitudinal monitoring and remote clinical evaluation.

2.1 Hardware part

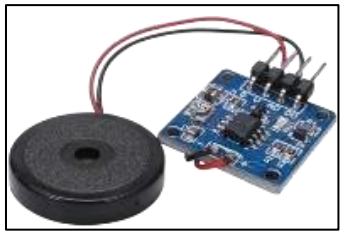

Figure 7: Piezoelectric sensor

The piezoelectric sensor is used to measure hand tremors, one of the hallmark symptoms of Parkinson's disease. It functions by converting mechanical stress into electrical signals, enabling detection of tremor frequency and amplitude. Its high sensitivity, rapid response time, and broad dynamic range make it suitable for capturing subtle involuntary hand movements. In this device, the piezoelectric sensor is integrated with the microcontroller to provide real time tremor monitoring, as shown in *Figure 7*. The sensor's ability to detect both low- and high-frequency vibrations enhances its reliability for continuous, non-invasive symptom tracking (Kazi et al., n.d.), (De Fazio et al., 2025).

Figure 8: FSR Sensor

The force-sensitive resistor (FSR) sensor is employed to assess muscle strength, which is essential for evaluating motor function in Parkinson's patients. The sensor changes its resistance based on the applied pressure decreasing resistance indicates increasing force. FSR sensors are lightweight, flexible, and well-suited for wearable applications. In this project, they are placed at the thumb, index/middle, and middle/pinky fingers to monitor hand muscle strength. When pressure is applied, the FSR sensors generate electrical signals that are processed by the microcontroller to evaluate muscle force, as illustrated in *Figure 8*. Their sensitivity and adaptability support accurate, real-time detection of fine motor impairments (H. Zhao et al., 2023).

2.2 Software part

The NodeMCU ESP32 CP2102 is the main controller used in this project. It is a development board with built-in Wi-Fi and Bluetooth, making it suitable for IoT applications. The CP2102 chip acts as a USB-to-serial converter, allowing easy connection to a computer for programming. In this device, the ESP32 collects data from the piezoelectric and FSR sensors, processes the signals, and sends the information wirelessly to the Blynk IoT platform. This allows real-time monitoring of hand tremors and muscle strength through a smartphone or computer. The ESP32 is chosen for its fast processing, low power usage, and ability to handle multiple sensors at once. Its integration into the system is shown in *Figure 9*, where it manages sensor data, wireless communication, and live display of readings. This makes the ESP32 a reliable and efficient part of the wearable IoT device.

3.0 RESULT AND DISCUSSION

3.1 Tested Subject

To test the usability of a Wearable IoT-based device for Parkinson's Symptoms detection using tremor and hand strength sensors (Wi-ParkSense), an experiment was conducted on subject A, where subject A was a participant with parkinson's symptoms in his early 80s. The subject was required to be attached to the Wi-ParkSense showed in figure 9 for 1 minute to 5 minutes gradually, to compare the values measured from the participants in terms of hand tremor and hand muscle strength from the thumb, index finger and middle finger. Next, the result obtain from Blynk Apps is recorded.

3.2 Experimental Setup

The focus of the experiment is to collect and monitor hand vibrations/tremor and hand muscle strength of participants with Parkinson's disease for usability testing. Participants will be fitted with Wi-ParkSense while at rest.

Figure 9: Participant was attaching with (Wi-ParkSense).

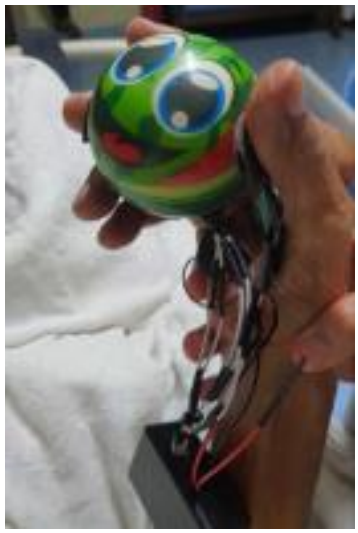

Figure 10: Participants do grip strength exercises with mini ball

In Figure 10, subject A tries to hold and press a mini ball to test hand strength using his thumb, index finger and middle finger within 1 to 5 minutes.

Automatic data collection was carried out by the patient based on usability testing, for which the experiment conducted on subject A is shown in graphs 11,12 and 13 which show the thumb, index finger and middle finger results for 1 minute to 5 minutes. At the same time, these results were recorded in the Blynk application.

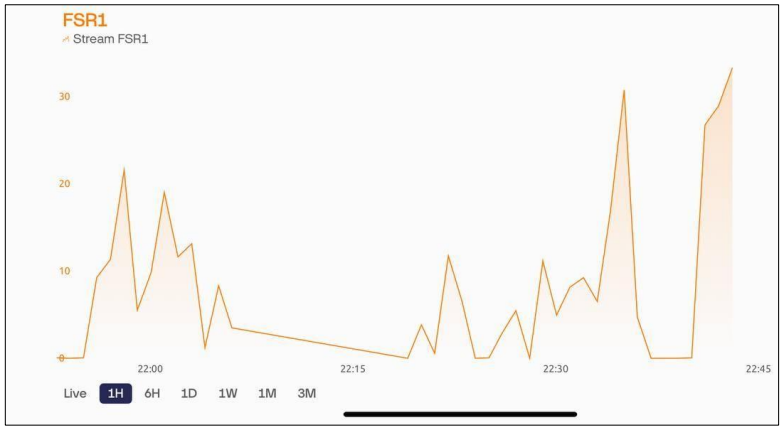

Figure 11: Graph FSR1 sensor for thumb finger

The graph in Figure 11 shows the muscle strength of the thumb. It begins with a quick increase above 20 N, indicating a brief effort. However, the strength soon falls below 10 N and then varies irregularly between 10 and 15 N. This pattern suggests difficulty in keeping a steady thumb strength, which is likely caused by symptoms such as muscle stiffness and slow movement (bradykinesia) common in Parkinson's disease.

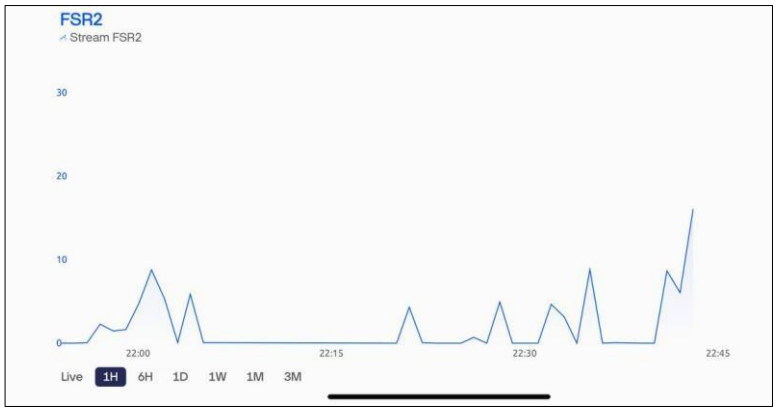

Figure 12: Graph FSR2 sensor for index finger

Figure 12 displays the strength data for the index finger, with values ranging between 4 and 12 Newtons. The force initially rises to around 10 Newtons, then gradually decreases to 6 and 4 Newtons, punctuated by brief increases reaching up to 12 Newtons. These fluctuations highlight challenges in sustaining a steady grip, suggesting weak and irregular muscle control.

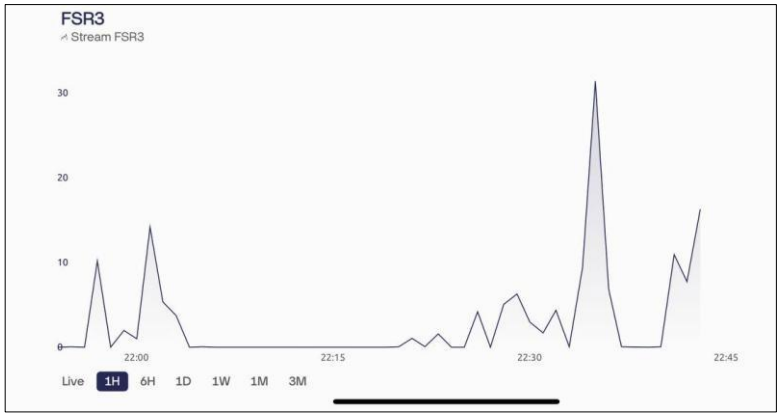

Figure 13: Graph FSR3 sensor for middle finger

Figure 13 focuses on the middle finger. The strength starts at 10 N, peaks at 14 N, then drops sharply to 5 N, briefly increases to 7 N, and falls again to as low as 2 N. This pattern suggests the patient struggles to keep consistent force, which is common in Parkinson's due to poor motor coordination. Overall, based on the data from all three fingers, the average hand muscle strength during the grasping task is estimated to be between 8 to 14 N, which falls under the range of moderate muscle weakness. This result is aligned with common symptoms of Stage 5 Parkinson's disease, where fine motor skills and grip strength are significantly affected. The inconsistent readings across all fingers confirm that the patient has trouble in sustaining hand force, supporting the effectiveness of the device in detecting motor impairments during daily tasks.

This graph in figure 14 shows the frequency data recorded over five minutes by the first piezoelectric sensor placed on the palm. The frequency fluctuates between 0 Hz to 2 Hz, aligning with the resting tremor characteristics of Parkinson's disease, which typically fall within the 4–6 Hz range but may appear lower in initial stages or under medication influence. The fluctuating pattern indicates variation in tremor intensity, providing insight into the episodic nature of resting tremors. Such data is critical in real-time monitoring to identify changes in tremor amplitude and frequency during daily activities.

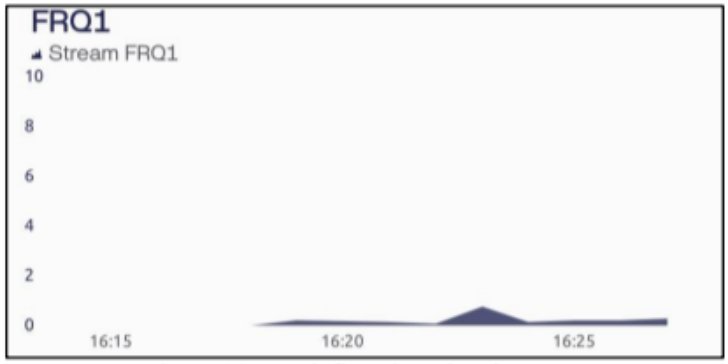

Figure 14: Graph first piezoelectric sensor

The second piezoelectric sensor's graph in figure 15 reveals initial tremor frequencies between 1 Hz to 2 Hz, showing periodic increases and decreases in intensity. This sensor provides additional confirmation of the tremor patterns observed in Figure 12, reinforcing the reliability of the device's tremor detection capability. The dynamic changes may represent tremor bursts followed by brief muscle control recovery phases. These insights are crucial in tailoring patient treatment plans and understanding how Parkinsonian symptoms manifest in natural, uncontrolled environments.

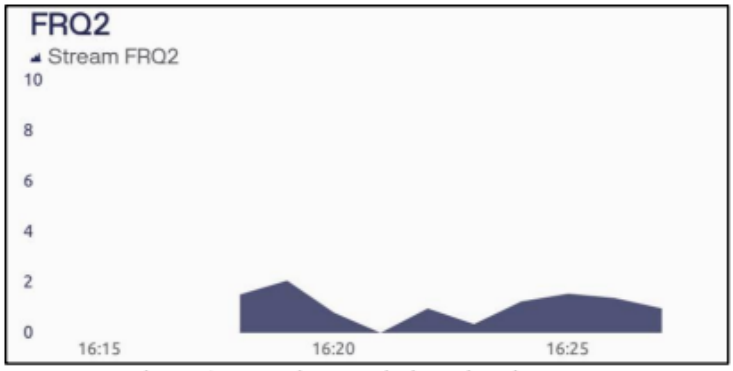

Figure 15: Graph second piezoelectric sensor

4.0 CONCLUSION

In a nutshell, the developed wearable IoT-based device, Wi-ParkSense, demonstrates a promising approach for real-time detection and monitoring of Parkinson's disease symptoms by integrating piezoelectric sensors for tremor detection and force-sensitive resistors for hand strength assessment. The system's ability to continuously capture and transmit motor function data via an Arduino Nano and ESP32 module to an IoT platform with Blynk apps addresses the limitations of episodic clinical evaluations, enabling early symptom recognition and ongoing disease management outside clinical settings. Experimental results from testing on a participant with Parkinson's symptoms showed measurable variations in tremor frequency and hand muscle strength, validating the device's functionality and potential for practical use. This affordable, user-friendly solution could significantly enhance accessibility to continuous monitoring, especially in regions with limited healthcare access, and support timely interventions that may slow disease progression. Future work may focus on expanding testing across diverse patient groups and refining data analytics to further improve diagnostic accuracy and usability.

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4 TEKNOLOGI PENGURUSAN FASILITI

A Study on Barriers of Effective Communication Within the Concession Company in Educational Institution

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ABSTRACT

This study aims to investigate the barriers that affect effective communication within concession facility management companies operating in educational institutions, focusing specifically on Universiti Teknologi MARA (UiTM). The objective is to identify the most significant communication challenges and propose practical strategies to enhance workplace communication and service delivery. The main problem addressed in this study is the persistent communication breakdowns that occur due to organizational structure, language and cultural differences, and physical or environmental limitations. These barriers impact operational efficiency, stakeholder engagement, and employee coordination. A quantitative research design was adopted, utilizing structured questionnaires as the primary data collection instrument. The sample consisted of employees from three concession companies, selected through non-probability convenience sampling technique to ensure representation across different levels of employment. Data were analyzed using the Statistical Package for the Social Sciences to determine trends and the most prevalent communication barriers. The findings revealed that organizational barriers were the most critical, followed closely by physical and environmental barriers, with language and cultural differences being less significant but still present. Issues such as communication silos, bureaucratic complexity, and poor feedback systems were identified as major obstacles. The study recommends implementing clearer communication frameworks, reducing procedural delays, upgrading communication infrastructure, and conducting staff training to improve clarity and collaboration. These initiatives are expected to significantly enhance communication flow, operational productivity, and teamwork across concession facility operations in educational environments.

Keywords: barriers, communication, effectiveness, concession, employee.

1.0 INTRODUCTION

1.1 Research Background

Facility management concession companies are responsible for the upkeep and maintenance of educational facilities, and their performance depends heavily on effective communication among employees, management, and clients. In the context of UiTM, these companies operate in diverse environments where employees hail from various cultural, linguistic, and professional backgrounds. According to Mahmud et al. (2020), such diversity, while beneficial in many ways, introduces complexities in communication that can lead to operational inefficiencies. Challenges such as rigid organizational structures, lack of transparency, unclear reporting lines, and varied communication styles often hinder the seamless flow of information.

In addition, concession companies at UiTM must respond quickly to maintenance issues and ensure continuous collaboration between internal teams and the university's administrative staff. Studies have shown that breakdowns in communication often lead to service delays, reduced stakeholder satisfaction, and conflict within teams (Summers, 2010; Daud et al., 2017). Therefore, understanding and addressing these barriers is essential for improving

communication dynamics, enhancing service quality, and fostering a more collaborative work culture.

1.2 Aim and Research Objectives

The aim of this research is to investigate the barriers to effective communication within concession facility management companies operating in educational institutions, particularly at UiTM. This study seeks to identify and analyze the specific challenges that hinder effective communication in the workplace, such as organizational, cultural, and environmental factors. Through this investigation, the research intends to develop targeted strategies to enhance communication effectiveness. The objectives supporting this aim are to identify the communication barriers faced by employees in concession companies, analyze the most significant of these barriers, and propose actionable recommendations to improve workplace communication and ultimately enhance service delivery and collaboration among stakeholders.

2.0 LITERATURE REVIEW

2.1 Effectiveness Communication in Workplace

Effective communication in the workplace plays a pivotal role in ensuring organizational success. Bucăța and Rizescu (2017) emphasize that communication enhances employee productivity and coordination, especially in environments characterized by cultural and professional diversity. Furthermore, with the increasing reliance on digital platforms for virtual meetings, the need for clear and coherent communication becomes even more pronounced. According to Antony (2013), effective workplace communication facilitates timely decision making, reduces conflicts, and improves overall efficiency. In concession settings, where maintenance activities are time-sensitive, effective communication ensures proper task execution and alignment of goals across different teams.

2.2 Barrier of Communication at Workplace

Barriers to communication at the workplace include physical, linguistic, cultural, and organizational elements that obstruct the smooth exchange of information. Physical barriers such as environmental noise and inadequate facilities can disrupt verbal and non-verbal cues (Johnson, 2022). Language differences, particularly in Malaysia's multicultural context, pose challenges to mutual understanding and often result in misinterpretation (Yusof & Rahmat, 2020). Cultural differences can also affect communication styles and interpersonal relationships, as noted by Paramita and Carissa (2018). Organizational barriers like strict hierarchies and unclear job roles further complicate communication, reducing employee engagement and the flow of critical information (Boone, 2013).

2.3 Physical and Environmental Barriers

According to the Shannon-Weaver Model of Communication, physical elements such as noise, lighting, and temperature can interfere with message transmission (Fedaghi et al., 2009). In concession environments, poor acoustics and uncomfortable conditions can distract employees, limiting their ability to communicate effectively. Stans et al. (2017) argue that such environmental factors reduce concentration and increase the likelihood of errors, emphasizing the need for optimal working conditions to support effective communication.

2.4 Language and Cultural Barriers

Language and cultural diversity in the workplace can hinder communication by introducing misunderstandings rooted in differences in speech, idioms, and non-verbal cues. Zakaria (2017) explains that limited language proficiency leads to confusion and miscommunication,

especially in technical contexts. Additionally, Rajendran and Rajendran (2018) highlight the issue of dialects and jargon creating exclusionary communication practices. Cultural norms concerning personal space, eye contact, and expression also vary, potentially causing offense or misinterpretation (Remland, 2004). Training in intercultural communication and language support programs can bridge these gaps, fostering a more inclusive communication environment (Livermore, 2010).

2.5 Organizational Barriers

Hierarchical structures and centralized decision-making often slow down communication processes within organizations. Gudykunst and Kim (1997) emphasize that organizational culture can either facilitate or hinder communication depending on whether it encourages openness. Anderson et al. (2015) add that generational gaps and resistance to change also contribute to organizational barriers. Solutions such as flattening organizational hierarchies, encouraging feedback, and improving internal communication channels are essential for creating a transparent and responsive work environment. Figure 1 shows the conceptual framework for this study.

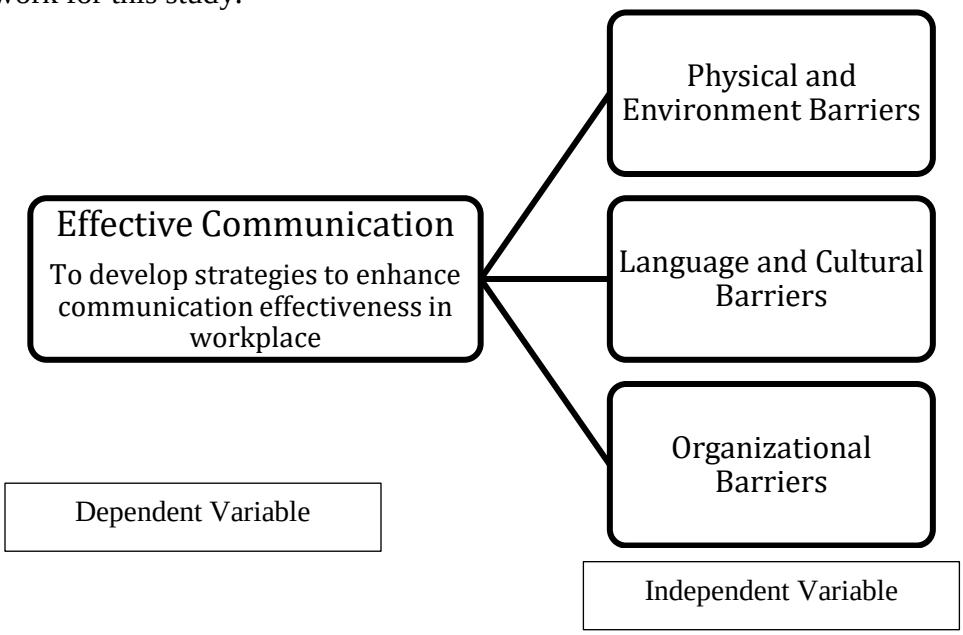

Figure 1: Conceptual Framework

3.0 METHODOLOGY

This research employs a quantitative research method, which is suitable for examining communication barriers through structured and measurable data. The quantitative approach enables the collection of numerical data that can be statistically analyzed to uncover patterns, frequencies, and relationships among the identified variables. By adopting this method, the study aims to objectively evaluate the extent and impact of communication barriers within concession facility management companies operating at UiTM.

The primary research instrument used is a self-administered questionnaire, specifically developed to capture relevant data from employees across different hierarchical levels. The questionnaire is structured into three sections:

- Section A: Respondent Demographic Data – This section gathers information regarding gender, age group, ethnicity, job position (e.g., manager, supervisor, technician), and level of management.

- Section B: Barriers to Effective Communication – This section employs a Likert scale to assess the frequency and intensity of communication barriers experienced by respondents. The barriers are categorized into three main groups: Physical and Environmental Barriers, Language and Cultural Barriers, and Organizational Barriers.

- Section C: Suggestions for Improving Communication – This open-ended section invites respondents to provide insights and recommendations on strategies to enhance communication effectiveness within their organizations.

The sampling technique utilized is non-probability convenience sampling, a method where respondents are selected based on their availability and willingness to participate. This approach ensures that the sample consists of employees who are directly involved in communication processes within the concession companies. The study targets employees from three concession companies operating at UiTM. The final sample size will consist of 143 employees, representing various roles such as managers, supervisors, technical staff and others.

For the data analysis, the study applies descriptive and frequency analysis to interpret the collected responses. Descriptive statistics will be used to summarize the demographic data and provide insights into the overall distribution of responses. Frequency analysis will help identify the most common communication barriers encountered by the respondents. All data will be analyzed using Statistical Package for the Social Sciences (SPSS) software, which ensures systematic, reliable, and accurate interpretation of the results.

4.0 RESULTS AND DISCUSSION

4.1 Respondents' Demographic Profile

The demographic profile of respondents is a crucial element in quantitative research as it allows the researcher to categorize the participants and understand the characteristics of the sample group. According to Bryman (2012), demographic data generally comprise personal information and behaviour-related details that assist in understanding trends and patterns in survey responses. In this study, demographic questions were designed to obtain information such as gender, age group, ethnicity, and job position of the respondents. These variables are important as they may influence how individuals perceive and experience communication barriers in the workplace. Moreover, demographic information contributes to the generalizability of the study and helps identify which group is most affected by communication challenges in concession companies. Table 1 shows the respondents' profile for this study.

Table 1: Profile of Responden (N=242)

Demography		Frequency	Percentage %
Gender	Male	83	58
	Female	60	42
Age Group	Under 28	23	16
	29-37	59	41
	38-46	36	25
	Above 47	25	17

Race	Melayu	97	68
	Indian	28	20
	Chinese	1	1
	Others	17	12
Position	Management	17	12
	Supervision	10	7
	Operational & Technical	37	26
	Cleaners	47	33
	Landscape Services	32	22

Demographic data were collected to understand the composition of the respondents and to examine potential influences on communication experiences in the workplace. A total of 143 participants from concession facility management companies responded to the survey.

The gender distribution comprised 58% male and 42% female respondents, indicating a relatively balanced representation. The majority of participants were aged between 29 and 37 years (41%), followed by those aged 38 to 46 years (25%), above 47 years (17%), and under 28 years (16%). In terms of ethnicity, 68% of respondents identified as Malay, 20% as Indian, 1% as Chinese, and 12% as other ethnicities. Regarding job roles, 33% of respondents were cleaners, 26% were operational and technical staff, 22% worked in landscape services, 12% held management positions, and 7% were supervisors.

This demographic distribution reflects a diverse workforce, allowing for a comprehensive analysis of communication challenges across various occupational and hierarchical levels.

4.2 Research Findings Objective 1

Descriptive statistics were employed to identify the level of perceived barriers to communication among respondents. This involved calculating the mean and standard deviation for each item within the three main variables. The interpretation of mean scores follows the scale proposed by Mohd Najib Abd Ghafar (2003), which categorizes the scores as low (1.00 – 2.33), moderate (2.34 – 3.67), and high (3.68 – 5.00).

Table 4 : Descriptive Statistics for Physical and Environmental Barriers (N=143, Mean=3.94)

Items	Mean	SD	Level
Physical and Environmental Barriers			
Background noise (e.g., air conditioning, loud conversations) disrupts my ability to understand messages.	3.95	0.944	High
An unconducive environment like dim lighting, uncomfortable temperatures, and noise can disrupt message clarity and communication.	3.92	1.021	High
Technical issues (e.g., poor internet connection, faulty phones) frequently disrupt communication.	4.15	0.866	High
Face to face meetings improve communication more effectively than online meetings.	3.88	1.084	High
The layout and distance between employees in the workplace hinder smooth communication.	3.80	1.154	High

The analysis of physical and environmental barriers in table 4 revealed an overall mean score of 3.94, which falls within the high range. This indicates that respondents strongly agreed that environmental factors significantly affect workplace communication. Among the five items under this category, the statement "Technical issues (e.g., poor internet connection, faulty phones) frequently disrupt communication" recorded the highest mean score of 4.15. This highlights the importance of reliable technological infrastructure in facilitating clear and effective communication, especially in operational settings.

Table 5 : Descriptive Statistics for Language and Cultural Barriers (N=143, Mean=3.72)

Items	Mean	SD	Level
Language and Cultural Barriers			
The usage multiple languages (e.g., local language and English) in communication causes confusion and misunderstandings.	3.66	1.162	Moderate
Different accents, dialects, or rapid speech sometimes led to miscommunication.	3.76	1.063	High
The use of technical jargon and unfamiliar terms creates barriers to understanding.	3.80	0.975	High
Cultural differences, including workplace norms and non-verbal cues, contribute to communication breakdowns.	3.66	1.094	Moderate
Employees from different backgrounds struggle to adapt to workplace communication styles.	3.71	1.143	High

Language and cultural barriers in table 5 received an overall mean score of 3.72, which also lies in the high category. Although slightly lower than physical and organizational barriers, this score still reflects a significant challenge to effective communication. The item "The use of technical jargon and unfamiliar terms creates barriers to understanding" recorded the highest mean score of 3.80. This suggests that employees often struggle to understand workplace communication due to the use of specialized or overly complex language.

Table 6 : Descriptive Statistics for Product (N=143, Mean=4.02)

Items	Mean	SD	Level
Organizational Barriers			
The company's hierarchical structure limits open communication.	3.97	0.964	High
Excessive bureaucracy (strict official rules and procedures in an organization) and complex procedures slow down communication processes	3.97	1.031	High
Lack of clear roles and responsibilities leads to confusion in workplace communication.	3.88	0.989	High
There are insufficient feedback mechanisms for employees to share concerns about communication challenges.	3.90	1.002	High
Communication silos (a situation where departments or teams work separately without sharing information) hinder cross-functional collaboration within the organization	4.38	0.787	High

Language and cultural barriers in table 5 received an overall mean score of 3.72, which also lies in the high category. Although slightly lower than physical and organizational barriers, this score still reflects a significant challenge to effective communication. The item "The use of technical jargon and unfamiliar terms creates barriers to understanding" recorded the highest mean score of 3.80. This suggests that employees often struggle to understand workplace communication due to the use of specialized or overly complex language.

Organizational barriers emerged as the most significant communication obstacle, with an overall mean score of 4.02 that showed in table 6. This high score indicates that structural and procedural issues within the concession companies are a major impediment to communication. The highest-rated item in this category was "Communication silos hinder cross-functional collaboration within the organization," which received a mean score of 4.38. This suggests that a lack of information sharing across departments is a serious issue that hampers efficiency and collaboration.

4.3 Research Findings Objective 2

Descriptive statistics were employed to identify the level of perceived barriers to communication among respondents. This involved calculating the mean and standard deviation for each item within the three main variables. The interpretation of mean scores follows the scale proposed by Mohd Najib Abd Ghafar (2003), which categorizes the scores as low (1.00 – 2.33), moderate (2.34 – 3.67), and high (3.68 – 5.00).

The descriptive statistics in this study were analyzed to examine the three main categories of communication barriers within the workplace, which are Physical and Environmental Barriers, Language and Cultural Barriers, and Organizational Barriers. The average mean scores were calculated for each variable to identify the most significant factors affecting communication effectiveness among employees of the concession companies operating at UiTM that shows in table 7.

Table 7 : Mean for variable (N=143)

Variables	**Mean**
Physical And Environment Barriers	3.94
Language and Cultural Barriers	3.72
Organizational Barriers	4.02

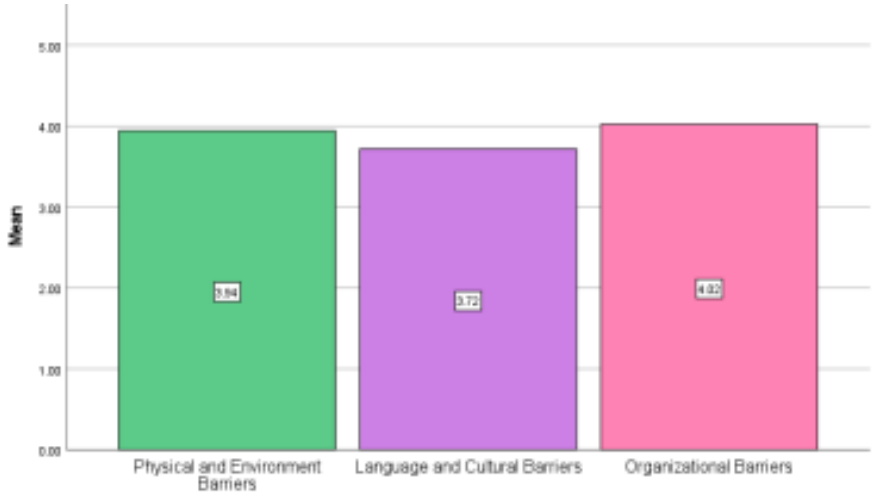

Figure 1: Graph Mean for variable (N=143)

The graph shown in Figure 1 indicate that Organizational Barriers recorded the highest mean score of 4.02, followed closely by Physical and Environmental Barriers with a mean of 3.94, while Language and Cultural Barriers had a slightly lower mean of 3.72. These findings suggest that structural and procedural issues within the organization have the most significant impact on communication, compared to challenges arising from environmental conditions or linguistic and cultural differences. This analysis is essential in identifying which barrier requires the most immediate attention to enhance communication practices and overall workplace efficiency among employees of the concession companies.

4.4 Research findings Objective 3

Descriptive analysis was conducted to assess respondents' levels of agreement with various proposed measures aimed at mitigating communication barriers. The analysis incorporated both quantitative data, derived from mean scores on a Likert scale, and qualitative insights gathered from open-ended responses. This section presents the communication improvement strategies most endorsed by employees and highlights additional recommendations based on their perspectives. Table 8 shows the suggestions communication improvement strategies from the responden.

Table 8 : Suggested Communication Improvements (N=143)

Recommendation	Mean
1. Provide better communication facilities, such as a clear audio system, soundproof meeting rooms, and digital information channels to reduce physical and environmental distractions	4.13
2. Use a standard communication language in documents, meetings, and work instructions to ensure all employees clearly understand the information.	4.22
3. Reduce bureaucratic barriers by allowing employees to communicate directly with top management without having to go through multiple layers of hierarchy	4.38

4. Use technology such as instant messaging apps, integrated information management systems, and official email to speed up information delivery	4.26
5. Provide dedicated spaces for employees to give feedback, whether through regular meetings, surveys, or digital platforms, so that their voices are heard	4.56

The highest-rated strategy was the establishment of effective feedback mechanisms, with a mean score of 4.56, indicating that employees strongly value opportunities to express concerns and contribute ideas. This was followed by calls to minimize bureaucratic barriers and promote direct communication with senior management (4.38). The integration of communication technologies such as instant messaging applications and centralized systems also received high support (4.26), alongside the need to standardize language use (4.22). Although rated slightly lower, improvements to the physical communication environment (4.13) were also generally supported.

In addition to the quantitative responses, qualitative feedback provided further insight into employee preferences and suggestions. Several recurring themes emerged:

- **Clear and direct communication**: Respondents emphasized the importance of using simple, unambiguous language and avoiding jargon or technical terms that could lead to misunderstanding.
- **Timely and centralized communication tools**: There was a strong preference for reliable and immediate information sharing through channels such as WhatsApp, emails, notice boards, and intercom systems. Participants also highlighted the need for centralized information sources to reduce confusion.
- **Respectful and supportive communication culture**: Employees expressed the desire for a workplace environment characterized by mutual respect, professionalism, and empathy. Communication should be free of harsh tones, public criticism, or emotional outbursts.
- **Inclusive and two-way communication**: Many respondents stressed the importance of being heard and included in decision-making processes. Suggestions included more interactive meetings, question-and-answer sessions, and inclusive discussions at all levels of employment.
- **Structured communication procedures and training**: The implementation of clear Standard Operating Procedures (SOPs), visual communication aids such as flowcharts, and regular communication training were identified as key strategies to improve understanding and consistency in message delivery.

5.0 CONCLUSION

This study explored the barriers to effective communication within concession facility management companies at Universiti Teknologi MARA (UiTM) and found that organizational barriers such as rigid hierarchies, unclear responsibilities, and limited feedback mechanisms were the most significant. These were followed by physical and environmental factors including disruptive layouts and unreliable technology, and then language and cultural differences. These communication challenges negatively impact operational efficiency, service delivery, and team collaboration. To address these issues, the study recommends implementing structured communication systems, minimizing bureaucratic processes, upgrading communication technologies, and providing continuous staff training in communication and

cultural awareness. For future research, it is recommended to expand the study to include larger concession companies with broader operational scopes and to identify additional communication barriers such as psychological, generational, or technology-related issues. Incorporating qualitative methods like interviews or focus groups could offer deeper insights and contribute to more effective and tailored communication strategies within facility management organizations.

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A Study on the Accessibility of Facilities for People with Disabilities (PWD) in Commercial Buildings in Shah Alam: Evaluation and Recommendations for Improvement

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ABSTRACT

This study seeks to evaluate the accessibility of facilities for people with disabilities (PWD) in commercial buildings in Shah Alam, Selangor, identifying gaps in accessibility and proposing suitable changes to address them. The lack of inclusive infrastructure and mobility aids available, especially in urban areas, continues to impede the movement, safety, and autonomy of PWD in public spaces and public transport. The primary concern is to assess the level of compliance with set accessibility standards and recommend modifications that would increase the comfort and usability of the facilities for PWD. The research method for this study is document analysis, where design plans, accessibility audit reports, and relevant technical documents are examined to evaluate compliance with MS 1184:2014 compliance requirements. The study revealed a considerable number of commercial buildings with inadequate compliance to designated legal requirements, especially concerning PWD access ramps and appropriate accessible toilets. The founding shown that facility maintenance issues greatly impeded progress. To enhance accessibility, this study suggests tailored infrastructure changes, formulation of contextualized technical standards, as well as training programs for facility managers. These considerations are constructive as they aim at policy changes designed to enhance PWD (Persons with Disabilities) access to commercial buildings and foster an inclusive urban ecosystem.

Keywords: accessibility, people, disabilities, facilities, commercial

1.0 INTRODUCTION

1.1 Research Background

Freedom of access to the built environment is a human right for all, meaning everyone, including the estimated 15% of Persons with Disabilities (PWD) in Malaysia, as defined by the Department of Social Welfare Malaysia. Universal design goes beyond the bare minimum provisions and seeks to ensure that all people regardless of age, ability, or social standing can navigate spaces without needing aids.

In relation to Malaysia, comprehensive policy initiatives have been developed in legislative and regulatory frameworks to enhance PWD access. The legal instruments pertaining non discrimination and disability rights are anchored in the Persons with Disabilities Act 2008 (Act 685) while universal design implementation in built environments is covered in the Malaysian Standard MS 1184:2014. These policies are in tandem with Malaysia's commitment to the UN Convention on the Rights of Persons with Disabilities (CRPD), which Malaysia ratified in 2010.Despite the above policies, there is still a major gap between setting-accessibility standards and actual standards achieved in Malaysian urban commercial developments, as

highlighted by numerous audits and empirical research. Given Malaysia's rapid urbanization and growing commercial concentration of vital services, this remains a worrying compliance gap.

1.2 Aims and Research Objective

This study investigates the accessibility of facilities for Persons with Disabilities (PWDs) in commercial buildings in Shah Alam and proposes enhancements following Malaysian Standard MS 1184:2014 and other relevant international standards. This work uses a three stage methodology: first, applying the access audit framework developed by Hashim et al. (2021) on the available PWDs' facilities on selected commercial buildings; second, evaluating the compliance of these buildings with the MS 1184:2014 Universal Design and Accessibility guidelines by conducting accessibility interviews; and third, developing conclusions and recommendations from international benchmarks particularly the WHO (2023) guidelines.

2.0 LITERATURE REVIEW

2.1 The Built Environment and the Principles of Universal Design in Malaysia

The existing body of literature indicates a glaring gap in the universal design consideration in the built environment in Malaysia with respect to the benchmark MS 1184:2014. A landmark study by Hashim et al. (2021) that audited 200 commercial buildings within five metropolitan centres of Malaysia showed that only 45% of the buildings fulfilled the minimum accessible feature requirements. This is alarming, especially considering that many of the buildings that were assessed were relatively new, and therefore, the integrated accessibility features would have encountered lesser challenges. In addition to these findings, Kamarudin et al. (2022) reported four key reasons contributing to the inadequacy: an initial design that does not incorporate universal design principles during the planning phase, a lack of enforcement by the local governing body, neglect in upkeep of accessible design elements as infrastructure components, and apathy from legal duty bearers of disability rights legislation concerning their responsibilities. In their comparison of accessibility standards in ASEAN countries, Abdul Rahman and Ibrahim (2022) found that in Malaysia, the presence of a well-defined, technical framework does not translate into implementation as a practical working measure when compared to Thailand or Singapore, thus revealing a substantial gap in performance.

2.2 International Frameworks and Best Practices

The policies on universal design are anchored on the United Nations Convention on the Rights of Persons with Disabilities (CRPD), which especially emphasizes in Article 9 that access is a mandatory social construct that must be granted to persons with disabilities in order for them to be fully integrated within the sphere of social participation. The implementation, however, differs from country to country. In Australia, the enforcement system with the Disability Discrimination Act 1992 and its accompanying Disability Access Standards is a strong example where legal obligations and supportive frameworks coexist. The US actively applies the Americans with Disabilities Act (ADA), which offers binding and comprehensive technical provisions shaped over 30 years of practice. In Asia, Japan's aggressive approach toward universal design, particularly in the lead-up to the 2020 Paralympic Games, illustrates how strong governmental impetus can greatly enhance accessibility infrastructure in the public and private sectors.

2.3 Impact of Accessibility from an Economic and Social Perspective

The World Health Organization (2023) recently released data that supports the sociocultural and financial ramifications of poor accessibility. The lack of enabling infrastructure results in

the side-lining of disabled people fully engaging in economic and social life which has tangible impacts on productivity and social cohesion within a nation. Lack of infrastructure hampers economic productivity, with a forecasted 3-7% loss from GDP on a yearly basis. Spending on infrastructure certainly provides great returns. Accessibility of physical spaces improves participation of disabled persons in the workforce, increases the available consumer market, and decreases long-term welfare and healthcare expenditure. All these factors have a positive economic impact. Studies conducted by the European Union regarding expenditures on infrastructure proved that for every 'one euro' spent on accessibility features, 'seven euros' were returned. This proves the long-term benefits of spending on infrastructure and the need for universal design.

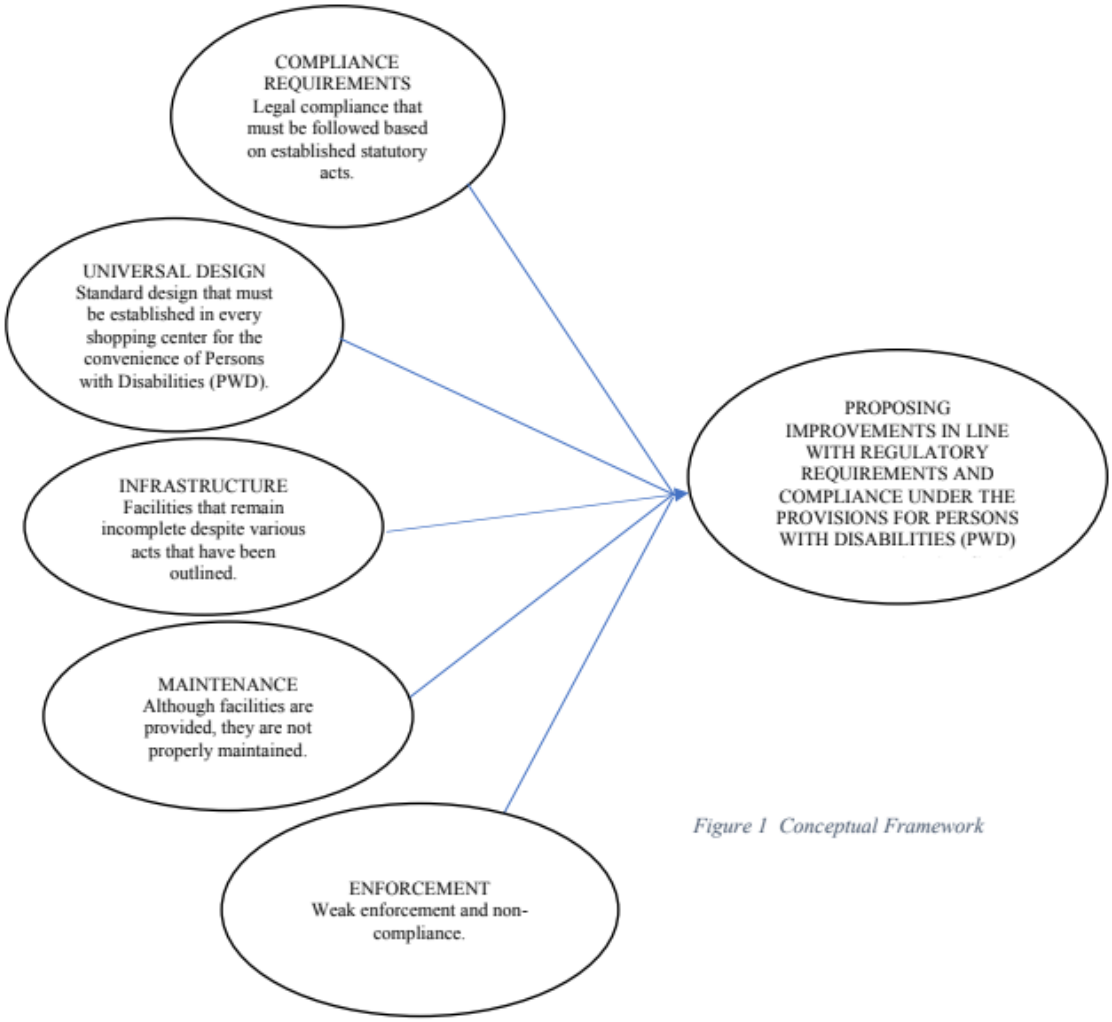

Figure 1 Conceptual Framework

3.0 METHODOLOGY

3.1 Quantitative Method

To measure and evaluate accessibility for the disabled (OKU) within commercial buildings, this research implements a quantitative approach. This method comprises systematic observation of physical facilities where measuring tools are used to capture the pertinent dimensions, specifications, and compliance levels in construction benchmarks; structured checklist evaluation based on MS 1184:2014 for scoring each component on the prescribed checklist as marked evaluation within the stipulated scoring framework; and document

assessment of building plans, compliance certificates and maintenance documents to check the technical description against the documents for claim verification, regulatory accuracy and adherence. The collected information undergoes analysis using statistical software to compute compliance rates, accessibility metrics, gaps between existing facilities and benchmarked requirements along with exposed objective and measurable findings and evidence-based improvement recommendations.

3.2 Site selection and sample size:

This case study examines the accessibility features of commercial buildings in Shah Alam, Selangor. To tailor the study sample as close as possible to represent the population, a purposive sampling technique was used to refine the selection criteria. Those criteria included: the commercial building had to be publicly accessible and in the form of a shopping mall; it must have a floor area greater than one hundred thousand square feet; it must be between five and fifteen years old; it should have high daily foot traffic; and it had to be situated at a place that is heavily visited by people, including People with Disabilities (PWD). Using these criteria, the following three buildings were chosen: SACC Mall, PKNS Complex, and Plaza Alam Sentral. They differ in ownership, architectural design, age, and thus characterization, providing a realistic cross-section of the commercial built environment in Shah Alam. These strategic criteria improved the likelihood that the findings of the study would have wider relevance.

The purposive sampling strategy ensured that the selected sites conformed to the overall accessibility criteria in the Malaysian Standard MS 1184:2014, which is critical for assessing compliance evaluation for sample preliminary comparative benchmarking. Each of the buildings had been occupied for over five years, and each had large floor areas exceeding 100,000 square feet, which made them especially useful for studying the prevalent issues concerning accessibility in heavily used, large-scale metropolitan commercial structures. This research was based on a systematic accessibility audit and was underpinned by relevant the accessibility audit methodologies frameworks that involved checklists. The instruments aimed at determining the level of conformity to the principles of Universal Design as well as MS 1184:2014's scope of universal benchmark standards for components compliance.

3.3 Study Sample

The focus of this study was three specific commercial buildings within Shah Alam, Selangor, which were selected from a purposive sampling method with specific inclusion criteria. The selected buildings, SACC Mall, PKNS Complex and Plaza Alam Sentral, are all publicly accessible shopping malls with floor areas over 100,000 square feet and operational histories between 5 and 15 years. These locations were chosen because of their high foot traffic and patronage by diverse demographic groups including Persons with Disabilities (PWD) which allows for practical evaluation of accessibility standards. Each of these selected buildings capture different combinations of ownership use, architectural style, and age of construction, thus providing a representative snapshot of the accessibility situation in the commercial sector of Shah Alam. The defined criteria guarantee that the focus of the study is on metropolitan, heavily visited, and oversized urban facilities where user experience is greatly influenced by accessibility features, or lack thereof. The study focuses these areas to identify the most significant access challenges and propose the most impactful solutions for PWD.

3.4 Research Instruments

This research applied an accessibility assessment tool framed within the context of MBPJ (2015) standards to evaluate the commercial buildings' compliance with MS 1184:2014 and

principles of universal design, which aimed at facilitating access to persons with disabilities. The evaluation focused on essential accessibility components such as ramps, designated accessible parking, toilets for persons with disabilities, wayfinding and navigation tools for the facilities, lifts and elevators, as well as comprehensive emergency procedures for multi-faceted disability access. The research team conducted targeted site visits to verify each accessibility feature against the defined criteria, ensuring thorough documentation of all aspects. Alongside documentation, extensive photographs were taken to navigate towards improving identified gaps and strengthening successful accessibility measures. To achieve status verification and accuracy, physical observations were cross-examined with relevant documents such as architectural drawings, compliance reports, policy documents, maintenance records alongside existing accessibility frameworks.

This methodology of direct observation, photography, and document analysis offered a rigorous method for assessing the level of accessibility situated within the selected buildings. The facilities were analyzed against national standards and internationally accepted benchmarks for commercial accessibility, where information from different sources permitted an inclusive evaluation. Through following this methodology, the evaluation outcomes are expected to be reliable reflections of the actual situations that differently abled persons encounter in the commercial spaces.

3.5 Data Collection Procedure

The information was gathered during a two-week window dated April 2025 using a specific sequence intended to ensure that all relevant aspects pertaining to accessibility were documented. Each of the selected commercial structures was the focus of intensive field visits associated with comprehensive assessments based on the standardized audit checklist during business hours to capture representative user conditions. For this purpose, patterned qualitative observation techniques were used to assess in real time the compliance of features designated as access elements with the specified criteria in MS 1184:2014, documenting whether the necessary features were present and functional. Each recorded compliance was paired with photographs as a way to visually substantiate the documented status of the access features.

On-site evaluations were improved by reviewing relevant documents such as floor plans, maintenance logs, and internal policies on accessibility, when possible. This document review process corroborated the field observations and revealed the level of institutional commitment towards maintaining accessible environments. Throughout the entire data collection process, a non-intrusive protocol that upheld ongoing building activities and protected the privacy and dignity of all users, especially persons with disabilities, was maintained. This manner helped ensure that the research activities had no impact on the operations of the commercial facilities while capturing thorough accessibility data for analysis.

3.6 Data Analysis Methods

The analysis of each building, and level of compliance for the accessibility standards set within MS 1184:2014, was measured against the descriptive statistics methods. The methodology employed has a grading mechanism where each checklist item is scored “Compliant” or “Non Compliant” through structured observations of the grading rubric. The compliance rates were calculated by taking the compliant items over total checklist items for each category, and multiplying by a hundred yielding percent scores for facility attributes. The distribution of these compliance rates was further aggregated into six overarching groups: ramps, parking facilities, toilets, signage systems, circulation areas, and emergency systems to determine what accessibility features were most lacking. A thorough cross site analysis was done for all three locations to identify commonalties, institutional gaps, and best and worst practices of the tried

and tested building benchmarks. Further comparison refinements were made vis-a-vis national benchmarks (MS 1184:2014) and international standards such as WHO recommendations to identify gaps and establish benchmarking references. This approach made it possible to interpret the accessibility situations in a structured and quantifiable manner while ensuring uniform compliance with evaluation criteria.

3.7 Reliability and Validity

This checklist-based method incorporates some procedural steps toward achieving reliability as outlined in the previous section. As with any empirical work, the initial step here involved careful calibration of the audit checklist. Its construction was not random; it was derived directly from the MBPJ (2015) document, which is one of the authoritative governmental documents serving as a guideline for urban planning and building regulations in Malaysia. Moreover, every detail and criterion incorporated within the checklist was in full compliance with the national standard MS 1184:2014. This standard articulated the need for universal design and sources the local guideline and the national standard precisely guarantee that each item evaluated was properly defined, coherently consistent in its context, and reliably quantifiable against the national benchmarks for accessibility. Such a precis engineering mitigated variability during the audit resulted in higher data reliability.

In addition to watching the physical environment, the methodology used involved meticulously cross-checking findings with relevant documentation. Obtained evidence via the standardized checklist was compared methodically to a multitude of official benchmarks, which include scrutinizing particular clauses of MS 1184:2014 and any available corroborative documents and reports, architectural drawings, and compliance documents related to the buildings under audit. This meticulous verification not only substantiated the accuracy of the site-specific documentation, but also ensured all analyses of access compliance interpretable were aligned with officially documented requirements, industry standards, and widely accepted practices at the time. This layering technique eliminated the possibility of interpretation error, thus reinforcing the neutrality of the results.

Finally, to capture the entire assessment process more rigorously, an audit trail was developed which includes photographic evidence captured during the audits. Furthermore, photographs were captured for checklist items and features deemed non-compliant requiring detailed descriptions. These photographs validated scoring decisions substantiating each score assigned throughout the auditing phase. The evidence captured strengthened the findings while undeniably providing a link to the methodology used and ensuring objective scrutiny reinforcing the scientific rigor of the study outcomes.

In this case, reliance solely on physical audits would compromise the trustworthiness of the commercial buildings. Combining document analysis with physical audits enhances the trustworthiness as it provides a complete picture of the accessibility within commercial buildings and the extent to which the implementation aligns with the existing policies. Analytical outcomes will be discussed in the following chapter.

4.0 RESULT AND DISCUSSION

The checklist audits performed at SACC Mall, PKNS Complex, and Plaza Alam Sentral revealed differences in compliance with the standards defined under MS 1184:2014 spanning

ix thematic areas of accessibility. Below is a consolidated summary of these compliance results. (To obtain objective 1 and 2; to identify type of disabilities facilities and compliance to legal provisions)

Facility Assessed	SACC Mall	PKNS Complex	Plaza Alam Sentral
Ramp Accessibility	Compliant	Partially Compliant	Compliant
Accessible Parking	Compliant	Non-Compliant	Partially Compliant
PWD Toilets	Partially Compliant	Partially Compliant	Non-Compliant
Signage & Wayfinding	Non-Compliant	Non-Compliant	Partially Compliant
Circulation & Vertical Access	Compliant	Compliant	Compliant
Emergency Systems	Partially Compliant	Non-Compliant	Non-Compliant

Figure 2 Complience Outcome

The accessibility audit conducted across the three commercial buildings Plaza Sentral Shah Alam, SACC Mall, and PKNS Complex revealed mixed compliance levels with MS 1184:2014 standards. Below is a summary of the audit findings:

Accessibility Element	Plaza Sentral (%)	SACC Mall (%)	PKNS Complex (%)
Ramps	80	65	70
PWD Toilets	50	45	55
Designated Parking	90	85	80
Signage & Navigation	60	50	40
Maintenance Status	70	55	60

Source: Field Audit, 2025
Figure 3 Compliance Rate

The thorough checklist-based audits performed at SACC Mall, PKNS Complex, and Plaza Alam Sentral showed differing levels of compliance with the MS 1184:2014 standards meticulously within six areas of accessibility. More specifically, SACC Mall showed reasonable compliance in the core circulation pathways and ramp elements , which is an area of strength for the mall. However, this positive factor was mitigated by weaknesses concerning the provision of adequate visual signage and permanently accessible emergency systems ,

which clearly need addressing. In contrast, PKNS Complex had more pervasive problems, showing major gaps in the wayfinding signage as well as emergency preparedness. Alarmingly, only the most fundamental circulation pathways were compliant to the requisite accessibility benchmarks. In the same way, Plaza Alam Sentral did well to ensure accessible circulation throughout the centre, however, the other supportive critical accessibility features, especially the toilets for urgent care, were significantly lacking. Taken together, these disparate findings highlight the most urgent needs targeted strategic measures focused on all three audited commercial sites such as improving overall signage, upgrade the non-compliant toilet facilities, enhance emergency preparedness protocols over the tried and tested structures supplied. To obtains objective 3, those are the six (6) recommendations for the institution or building owner:

Recommendations

1. In consideration of the granular audit results along with the identified compliance gaps, the following key recommendations have been proposed to improve the accessibility of these commercial buildings in fostering a truly inclusive environment:
2. Allocate dedicated ongoing maintenance processes for all existing accessibility features. Timely and active maintenance is vital to ramps, lifts, tactile paving, and accessible toilets, elevating their safety and compliance through consistent care during operational periods. Active upkeep counteracts wear and enables persistent function for all users.
3. Allocate funds and resources to immediately implement comprehensive tactile and braille signage systems both inside and outside the perimeter of the buildings. Such supports, including tactile maps and braille signage at all critical interfaces, are imperative for aiding visually impaired friends navigate objects, independently move through spaces, and greatly enhance their experience in these commercial spaces.
4. Integrate specific retrofitting schemes for the sections or parts of the older buildings to bring them to the current compliance standards of ramps and signages. Structures coming into existence due to their age must undergo modifications to meet modern standards. This may include modifications to ramp slopes, handrail installation, as well as updated visual and tactile signage in compliance with MS 1184:2014 standards.
5. Encourage the establishment of localized and precise auxiliary technical documents. Localized guidance serving to accompany primary documents such as MS 1184:2014 is extremely beneficial if supplemented with practical examples and common mistakes that help to address the challenges faced by building owners, constructors as well as facility managers towards ensuring proper compliance to the said standards in the given locality.
6. Define stronger mechanisms to ensure the periodic audits of accessibility and compliance reporting by the local authorities concerned. Tight oversight, or even better, ongoing supervision is critical for holding building owners and management accountable. There is a perpetual struggle towards improvement in accessibility commercial building standards, and this persistent approach to compliance across the jurisdiction strengthens the culture of compliance as a whole.

5.0 CONCLUSION

With commercial buildings located within Shah Alam, Selangor, this research sought to focus on the accessibility issues for Persons with Disabilities (PWD) within the particular region. The results certainly indicate that some facilities do comply with Malaysian Standard MS 1184:2014, however with a large number of them showing significant shortfalls. These shortfalls are not only trivial matters, but rather disabling PWD from being able to

independently and safely navigate through public spaces.

As was previously described in the methodology audit, the described strengths were easily negated by weakness in PWD toilets, proper emergency aid services, and active relief systems for disabled persons. Overcoming these issues pose significant barriers that limit the accessibility that disabled persons have within mainstream social and economic activities and PWD further perpetuates discrimination by undermining the ideals of universal design as well as an inclusive built environment.

Thus, the conclusions drawn from this report are a striking message to escalate action. Standards alone are not adequate – proper application is discipline enforcement. The proposed comprehensive, proactive, and enforcement-suggestions begging, including command maintenance, tactiles wayfinding installations, localized governing frameworks, and stringent oversight, is binding and prioritized – are not merely suggestions to be debating, but essential actionable pivots. Implementation of the recommendations is critical to correct deficiencies identified and to advance towards building truly accessible urban spaces that enable and empower unencumbered mobility, participation, and flourishing unrestricted by needless barriers for all and at all levels. Shah Alam was converting to fully accessibility is the destination – these findings tell us how to get there.

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Assessing Awareness of Energy Management Practices Among Building Occupants at UiTM Tapah

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ABSTRACT
Energy management involves planning both energy production and use. All agents in society, from businesses to individuals, are more conscious of the importance of managing and using energy more efficiently in order to preserve the environment. Efficient energy management and sustainability are crucial for advancing society. Energy management Practices among Building Occupants plays an important role in advancing sustainable energy usage and efficient campus management. Lately, gaps in knowledge, communication and engagement, behavioural factors affect building occupant's awareness with energy-saving measures. Hence, it is crucial to assess awareness of energy management practices. In order to gather information on this subject, a survey was conducted using quantitative method. The questionnaire survey was distributed to 150 employees working in the administrative building of UiTM Tapah. Based on the Krejcie and Morgan (1970) sample size table, the required sample size for a population of 150 occupants is 108 respondents. The SPSS Software was used to analysis the quantitative data. The analysis indicates that while occupants of the UiTM Tapah building are well aware of energy management methods. knowledge had the highest mean, showing good comprehension, but Behavioural scores indicate that occupiers put this information into effect. Enforcement shows moderate to strong views on rules and monitoring. Communication had the lowest score, indicating a need to improve the way energy management information is disseminated in order to raise awareness and participation. The awareness and involvement of building occupants play a vital role in achieving energy efficiency goals.

Keywords: Awareness, Energy, Management, building, Occupant

1.0 INTRODUCTION

1.1 Research Background
Buildings consume more than 40% of global power and account for 30% of greenhouse gas emissions (JKR and CIDB, 2016). Nonetheless, energy simulations and the "green" building concept are extensively researched and developed to improve building performance. Throughout the building's life cycle, resource-efficient and environmentally responsible methods are employed to create green buildings that reduce energy consumption, greenhouse gas emissions, and other challenges (EPA, 2016). Furthermore, several countries have unique rating systems in place to determine whether a green building meets specified standards. Leadership in Energy and Environmental Design (LEED) is a program in the United States. The Building Research Establish Environmental Assessment Method (BREEAM) originated in the United Kingdom .In Malaysia, the Green Building Index (GBI) is one of the tools used to grade green buildings. A major obstacle to accomplishing this, though, is found within organizations themselves, where members' lack of enthusiasm and knowledge prevents the adoption and application of energy-saving strategies. This issue is especially noticeable in non Western countries like Malaysia, where organizational and cultural characteristics have a

significant impact on the willingness to adopt energy-efficient technologies. Although there has been significant advancement, less study has examined how these factors influence Malaysian firms' understanding and acceptability of energy efficiency techniques (Sofizain Bin Adam, 2023).Malaysia runs the risk of not meeting its energy conservation goals if it does not have a thorough grasp of the factors that encourage and hinder energy efficiency in the building industry (Prafitasiwi & Rohman, 2019).

1.2 Aim and Objectives

An aim was created to propose best practices in enhancing the awareness of energy management practices among building occupants at UiTM Tapah. At the end of this research, an appropriate recommendation will be produced to implementing effective energy efficiency practice according to the data collected. In order to achieve the study's goal and answer the research question, several specific objectives have been identified:

i. To identify the factors that affect the level of awareness among building occupants at UiTM Tapah regarding energy management practices.

ii. To analyze the factors that affect the level of awareness among building occupants at UiTM Tapah regarding energy management practices.

iii. To propose recommendation to enhance the factors that affect the level of awareness among building occupants at UiTM Tapah regarding energy management practices.

2.0 LITERATURE REVIEW

2.1 Definition of Energy efficiency

I. Energy efficiency, defined as units of output per unit of energy, refers to the efficacy with which energy is used to generate a specific service or good. The main benefits of energy efficiency, as it is commonly known, include a reduction in the amount of energy assets required to provide a specific level of energy service, which has an impact on asset consumption, energy security, and financial resources; and a reduction in carbon emissions and other toxic emissions, as well as the overall ecological impact associated with energy use (Ohueri et al., 2018).

II. Energy efficiency improvement is a basic yet significant way of addressing both energy security and environment concerns" and involves the "ways to measure how energy is efficiently/inefficiently used" using different performance indicators such as energy intensity, thermal efficiency, and diffusion of energy-efficient technologies (Tanaka, 2008)

III. "Using less energy to produce the same amount of services or useful output." For example, in the industrial sector, energy efficiency might be measured by how much energy is required to produce a tonne of product (Patterson, 1996).

2.2 Knowledge & Education

This factor suggests that an individual's existing knowledge, understanding, and educational background related to energy management practices would play a significant role in shaping their overall awareness and engagement in this domain. The implication is that improving people's knowledge and education about energy management could increase their awareness and adoption of these practices. (Prafitasiwi et al., 2022)

2.3 Communication

This factor indicates that the way information about energy management is communicated to individuals, through various channels, mediums, and messaging strategies, could impact their awareness and motivation to adopt energy management practices. Effective communication that resonates with people and makes energy management information accessible and actionable may be crucial for raising awareness (Patterson, 1996)

2.4 Behavioural factors

Behavioural factors represent the role that individual behaviours, habits, beliefs, motivations, and psychological tendencies might play in shaping a person's awareness and adoption of energy management practices. Factors like personal values, perceived benefits/barriers, social norms, and environmental attitudes could all contribute to behavioural responses related to energy management (Zhao et al., 2019)

2.5 Enforcement by institution

This factor suggests that the policies, incentives, regulations, and institutional mechanisms put in place by organizations, authorities, or governments could influence people's awareness and adoption of energy management practices. The implication is that stronger enforcement, mandates, or positive reinforcement from institutions may enhance individuals' awareness and engagement with energy management (Cibinskiene et al., 2020)

2.6 Conceptual Framework

The titled of the research is assessing awareness of energy management practices among building occupants at UiTM Tapah. There are 4 constructs formed in the framework of this study. The research framework is as below.

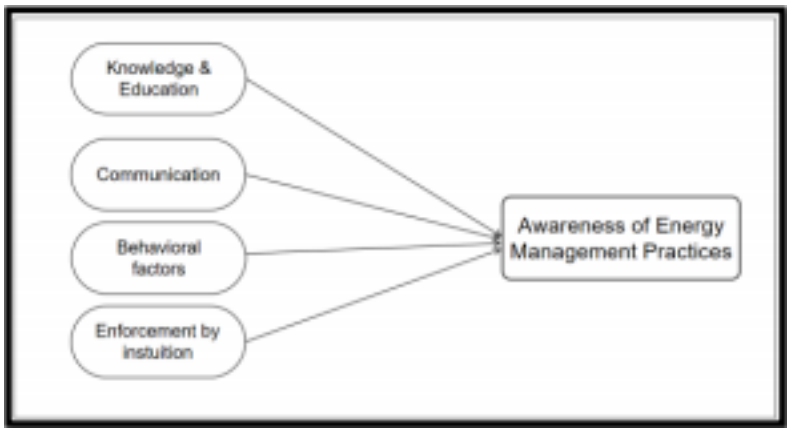

Figure 1 : Conceptual Framework

3.0 METHODOLOGY

Quantitative research is a method of gathering and analyzing numerical data to uncover patterns, test hypotheses, and make predictions. It focuses on quantifiable data and frequently use techniques such as surveys, questionnaires, or statistical analysis to collect data from a large number of respondents. The researcher has chosen a quantitative technique approach to gain the data required for the study's aims.

This study uses a quantitative research method because it allows for the collection of numerical data from a large number of respondents in a structured and objective way. The questionnaire used in this research consists of 35 items, including demographic questions and items related to energy management awareness.

This study focuses on assessing awareness of energy management practices among administrative building occupants at UiTM Tapah. The respondents chosen based on the fact that they only used the building during typical 8-5 office hours. It would be more accurate if I conducted a survey with them. Based on the Krejcie and Morgan (1970) sample size table, the required sample size for a population of 150 occupants is 108 respondents. The SPSS Software was used to analysis the quantitative data.

This study collects responses from UiTM Tapah's building occupants using a non probability sample approach, specifically convenient sampling. Descriptive analysis is used to summarize and describe the basic features of the data collected from your questionnaire. It helps to give a clear overview of the respondents' profiles and their responses to each question, especially those related to awareness of energy management practices.

4.0 RESULTS AND DISCUSSION

This chapter explains the outcomes of the data analysis and demonstrates how they align with the study's objectives. Questionnaires were delivered to UiTM Tapah's Administrative Building workers via Google Form. Despite obstacles, 80 responds provided an acceptable sample size for the organization's population, enabling successful data analysis. The findings are presented using diagrams, tables, and pie charts for simple comprehension. Data was processed with SPSS V.27. Data from Google Forms were transferred to Microsoft Excel and entered into SPSS. The investigation focused on computing percentages and means with SPSS.

4.1 Tables and Figures

The descriptive statistics were calculated for each item and variable to investigate their levels among the respondents. According to Mohd Najib Abd Ghafar (2003), the three levels of categories based on the mean are low (1.00 – 2.33), medium (2.34 - 3.67), and high (3.68 – 5.00).

Table 1 : Descriptive statistics for Knowledge (N=80,Mean 4.643)

No	Items Knowledge	Mean	SD	Level
1a)	Formal education or training in energy management is important.	4.72	0.573	High
1b)	The impact of energy-saving practices on the environment and economy is clear.	4.64	0.641	High
1c)	Awareness of the university's energy-saving initiatives and programs exists.	4.56	0.744	High
1d)	Energy-saving practices are crucial in institutional buildings to help reduce costs.	4.65	0.576	High

Table 1 shows the descriptive statistics for knowledge variable. Overall mean for knowledge is 4.643,indicating a high level of impact. Specific issues such educational essential (mean =4.72) and impact of energy saving practice (mean = 4.64) are all rated at a high level. The awareness of the university's energy saving initiatives is (mean = 4.56) and Energy-saving practices are crucial in institutional buildings to help reduce costs (mean = 4.65) also fall into the high category. The descriptive statistics indicate that the overall knowledge and its various aspects, including education importance, impact on energy saving, knowledge on awareness, and cost reduction, all fall within the high impact category.

The respondents' high mean scores on all knowledge variable-related items, which range from 4.56 to 4.72, show that they are well-informed about energy management techniques. This implies that the university's awareness-raising and educational initiatives have been successful. Knowledge is a major role in encouraging building occupants to adopt energy saving behaviours, as evidenced by the consistently high scores across several factors (such as the significance of education, awareness of programs, and cost-saving benefits). Consequently, the conclusion that knowledge has a significant influence on energy management awareness and practices is highly supported by the descriptive statistics.

Table 2 : Descriptive statistics for Communication (N=80,Mean 4.533)

No	Items Communication	Mean	SD	Level
2a)	Information about energy-saving practices is easily accessible (e.g., via email, posters, or announcements).	4.57	0.763	High
2b)	Discussions on energy management are encouraged within the institution.	5.56	0.672	High
2c)	The energy-saving goals and initiatives set by the university are clear.	4.49	0.729	High
2d)	Energy-saving reminders, such as posters, digital screens, or announcements, are frequently present within the UiTM Tapah campus.	4.51	0.675	High

Table 2 shows the descriptive statistics for communication variable. Overall mean for communication is 4.533 ,indicating a high level of impact. Specific issues such Information accessible (mean =4.57) and discussions encouraged within the institution (mean = 5.56) are all rated at a high level. The energy-saving goals and initiatives set by the university are clear is (mean = 4.49) and energy-saving reminders, such as posters, digital screens, or announcements, are frequently present (mean = 4.51) also fall into the high category. The descriptive statistics indicate that overall communication and its various aspects including information accessible, encouragement for discussion on energy management, energy saving goals, and reminders frequent consistently fall within the high impact category.

These findings imply that the university's communication tactics are successful in spreading ideas about energy conservation and creating a setting where energy management is actively

encouraged. Thus, it can be said that one of the main reasons why building residents are so aware and involved is communication.

Table 3 : Descriptive statistics for Behavioural (N=80,Mean 4.578)

No	Items Behavioural	Mean	SD	Level
3a)	Efforts are made to turn off lights and electrical appliances when not in use.	4.63	0.718	High
3b)	Peers and colleagues are encouraged to adopt energy saving behaviours.	4.60	0.704	High
3c)	Willingness to adjust daily habits to support energy management exists.	4.56	0.744	High
3d)	Observing others practice energy management serves as motivation to do the same.	4.53	0.693	High

Table 3 shows the descriptive statistics for behavioural variable. Overall mean for behavioural is 4.578, indicating a high level of impact. Specific issues such self efforts made(mean =4.63) and encouragement given by colleagues (mean = 4.60) are rated at a high level. The willingness to adjust daily habits is (mean = 4.56) and Observing others practice energy management serves as motivation to do the same (mean = 4.53) also fall into the high category. The descriptive statistics indicate that the overall behavioural has a high impact, with high ratings for efforts made and engouement given by colleagues, while willingness to adjust daily habits and observing others practice are at high levels.

These findings imply that behavioural elements, such as self-motivation, peer pressure, and habit modification, are favourably influencing the adoption of energy management techniques. Thus, it is evident from the high means of these indicators that behaviour is crucial to the institution's ability to support and maintain energy-saving measures.

Table 4 : Descriptive statistics for Knowledge (N=80,Mean 4.561)

No	Items Enforcement	Mean	SD	Level
4a)	The university has policies and guidelines on energy management.	4.62	0.666	High
4b)	Enforcement measures exist to ensure compliance with energy-saving policies.	4.58	0.742	High
4c)	Regular energy audits or monitoring activities are conducted to enforce energy-saving initiatives.	4.52	0.693	High

4d)	The university implements energy-saving campaigns and utilizes advanced technology, lighting elements, equipment, or products for energy efficiency.	4.54	0.711	High

Table 4 shows the descriptive statistics for enforcement variable. Overall mean for enforcement is 4.561, indicating a high level of impact. Specific issues such policies exist (mean =4.62) and Enforcement present to ensure compliances (mean = 4.58) are rated at a high level. Regular energy audits or monitoring activities are conducted to enforce energy-saving initiatives is (mean = 4.52) and the university implements energy-saving campaigns and utilizes advanced technology, lighting elements, equipment, or products for energy efficiency (mean = 4.54) also fall into the high category. The descriptive statistics indicate that overall enforcement by the institution and its specific aspects including the policies exist, enforcement present exist, regular audit conducted, and the technology utilized the medium impact category.

These findings suggest that enforcement mechanisms through policies, monitoring, and the use of technology are effectively encouraging energy-saving behaviours'. Therefore, the data confirms that enforcement is a critical factor with a consistently high impact on the successful implementation of energy management initiatives within the university.

The descriptive statistics for four primary categories knowledge, communication, behavioural and enforcement were examined to assess the awareness of energy management. Average means from each variable were analyzed to identify the factors that affect the level of awareness among building occupants at UiTM Tapah regarding energy management practices., as presented in Table 5.

Table 5: Mean for variable (N=80)

Variable	Mean
Knowledge	4.643
Communication	4.533
Behavioural	4.578
Enforcement	4.561

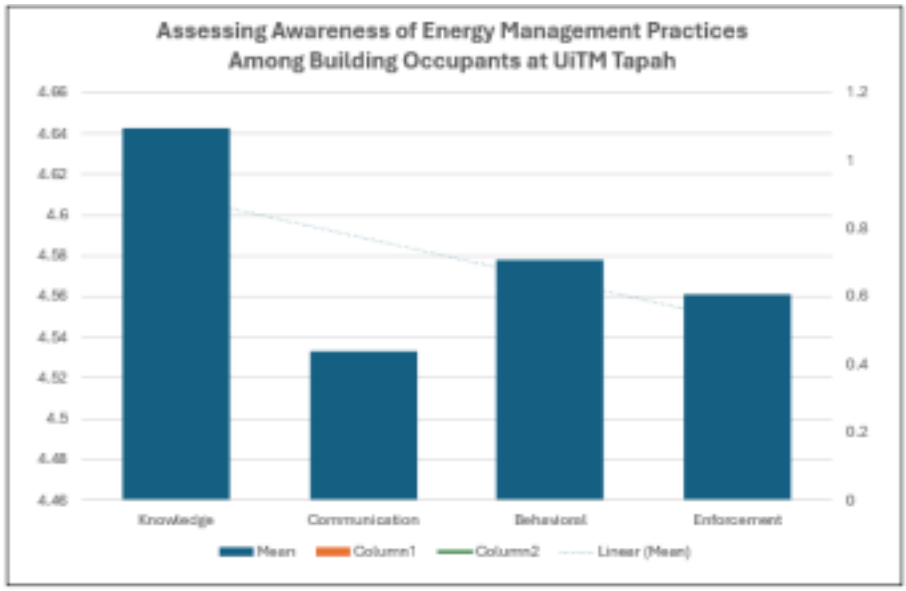

Figure 2 : Graph Mean for variable (N=80)

The graph in figure 2 shows the knowledge and behavioural have a more substantial analyzed factors that affect the level of awareness among building occupants at UiTM Tapah regarding energy management practices . The high score four factors influencing employee performance particularly critical factor. Knowledge has the highest (mean =4.64), indicating that building occupants are highly aware of energy management knowledge, such as concepts, techniques, or importance. Communication shows the lowest (mean =4.53).This suggests that communication related to energy practices (e.g., campaigns, signage, or announcements) may not be as effective or widespread. Behavioural and Enforcement scores are in the mid-range, with Behavioural being slightly higher (mean =4.57) than Enforcement (mean =4.56). This implies that while individuals may engage in energy-saving behaviour, enforcement mechanisms or policies might not be strongly felt. Addressing these factors can foster a more effective in assessing awareness of energy management among building occupants of Administrative building at UiTM Tapah.

5.0 CONCLUSION

The study assessed the level of awareness regarding energy management practices among building occupants at UiTM Tapah, focusing on key dimensions such as knowledge, communication, behavioural factors, and enforcement. It was also observed that building occupants' awareness contributes to energy management of a building. Overall, the study reveals that building occupants at UiTM Tapah demonstrate a high level of awareness in terms of energy management knowledge. However, communication efforts appear to be less effective, indicating a need for better information sharing and engagement strategies. While occupants are generally willing to practice energy-saving behaviours, the enforcement of related policies and guidelines is not strongly felt. These findings suggest that enhancing communication and strengthening enforcement can further support energy efficiency efforts. A balanced approach that includes awareness, behaviour change, and consistent policy implementation is essential for promoting sustainable energy management in the campus environment.

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Building Maintenance Under Scrutiny: Identifying Key Challenges in Malaysia's Higher Education Institutions

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ABSTRACT

Robust building maintenance management constitutes an essential for ensuring the operational integrity, environmental sustainability, and safety of campus infrastructure in Malaysian higher education institutions, which serves as an anchor for academic continuity and institutional quality. However, persistent structural issues continue to impede the efficacy of maintenance methods in many organizations. This research scrutinizes effective strategies to improve maintenance management standards at the three institutions of Universiti Teknologi MARA (UiTM), namely Tapah, Puncak Alam, and Dengkil. Using a quantitative research methodology, standardized questionnaires were distributed to 63 respondents, and the data was analysed using descriptive statistical techniques in SPSS. In accordance with the findings, major impediments include communication breakdowns, underutilization of digital tools like Computerized Maintenance Management Systems (CMMS), budget disbursement delays, insufficient inventory tracking mechanisms, and inconsistent implementation of preventive maintenance procedures. These limits drastically decrease infrastructure performance, reduce user satisfaction, and risk the long-term sustainability of institutional assets. The research paper emphasizes the need for a proactive, digitally connected maintenance infrastructure that includes simplified communication processes, efficient inventory systems, smart financial planning, and ongoing capacity building applications. These findings provide practical recommendations for institutional representatives and add considerably to the literature review of sustainable facility management in Malaysia's higher education environment.

Keywords: building, maintenance, higher-education, , facility, management

1.0 INTRODUCTION

1.1 Research background

Infrastructure inside Malaysia's higher education institutions, such as lecture halls, labs, libraries, dormitories, sports facilities and administrative buildings must be maintained in order to function properly. However, many of these institutions continue to encounter issues due to low funding and a lack of proactive maintenance methods (Hamzah et al., 2022). These limits frequently lead to delayed maintenance, rapid infrastructure deterioration, increased repair costs, and reduced safety standards (Ali & Yusof, 2021). The current emphasis on reactive maintenance, The current emphasis on reactive maintenance, which is only intervening when problems arise, is burdening operational efficiency and increasing long-term expenses (Kamaruddin et al., 2020). Furthermore, the lack of an integrated monitoring and evaluation system undermines the ability to analyze maintenance performance and allocate resources appropriately (Rahman & Hassan, 2024). Proactive techniques, such as frequent inspections and preventive maintenance, can significantly minimize the occurrence of major breakdowns, increase cost efficiency, and extend facility lifespan (Ismail & Said, 2023). As a result, academic and policy circles underline the urgent requirement for a sustainable and systematic maintenance management framework at Malaysia's higher institutions.

1.2 Aim

To propose strategic recommendations for enhancing maintenance management practices in Malaysian higher education institutions, using selected UiTM campuses, and to assess how these challenges influence the overall efficiency, functionality, and sustainability of campus facilities.

1.3 Research objectives

This research aims to achieve the following objectives:

a. To identify the main challenges faced in building maintenance management at Malaysian higher education institutions.

b. To analyze the challenges faced in building maintenance management at Malaysian higher education institutions.

c. To assesses the impact of the challenges faced in building maintenance management at Malaysian higher education institutions.

2.0 LITERATURE REVIEW

The literature review to this research underlines the ongoing challenges in developing maintenance management within Malaysian higher education institutions, notably in terms of funding limits, antiquated maintenance systems, fragmented communication, and inexperienced workforce.

2.1 Financial Management

The effectiveness of planning, prioritizing, and conducting maintenance tasks is largely dependent on financial management. Poor maintenance outcomes, such as postponed repairs, a lack of preventative work, and the use of inferior supplies, are frequently caused by a lack of money, delayed budget approvals, and strict procurement processes (Yusof et al., 2021). Universities without flexible budgeting frameworks are more likely to use reactive maintenance techniques rather than proactive ones, which raises long-term expenses and accelerates asset deterioration (Abdullah et al., 2022).

2.2 Operation and Maintenance

The daily administration of facilities, including planning, carrying out, managing, and assessing maintenance tasks, is referred to as operation and maintenance (O&M). Increased building defects and operational inefficiencies are directly related to poor O&M practices, such as irregular work orders, a lack of preventative maintenance schedules, or unskilled technical teams (Nor et al., 2020). Poor O&M performance in higher education may reduce user satisfaction, affect safety, and interrupt academic continuity.

2.3 Inventory Management

In order to facilitate rapid maintenance and resource availability, an efficient inventory system is necessary. Ineffective inventory control frequently results in duplicate equipment, untracked tools, and shortages of replacement parts, all of which raise operating expenses and postpone maintenance tasks (Hamid et al., 2023). Asset monitoring and condition-based maintenance planning are made more difficult by the lack of integrated digital platforms like CMMS or RFID tagging systems.

2.4 Communication

Communication acts as a critical enabler that binds the other dimensions together. Unresolved complaints, unclear work orders, and misplaced targets are frequently the outcomes of inefficient communication between categories, including maintenance, financial, and academic organizations. Facilities managers commonly point to inadequate internal communication as a major obstacle to prompt response and efficient maintenance job coordination, as noted by Lee and Hassan (2021).

3.0 METHODOLOGY

The research uses a quantitative research technique that is optimal for identifying, assessing, and generalizing the issues of building maintenance management in Malaysian higher education institutions. The quantitative method enables researchers to collect numerical data and use statistical analysis to uncover trends, patterns, and correlations. In this research, the strategy allowed the researcher to measure the severity of difficulties such as budgeting, personnel, inventory, and system management using structured questionnaires. This technique was also chosen for its speed in gathering data from numerous institutions within a short timeframe, which was required for comparative research across UiTM Tapah, Puncak Alam, and Dengkil.

3.1 Research Instrument

The primary instrument of research for this research is a structured questionnaire designed to collect accurate and quantitative data on the issues of building maintenance management. To ensure its relevance and comprehensiveness, the questionnaire was prepared after conducting an intensive examination of literature and engaging with experts in the field. The closed-ended questions, which mostly use a Likert scale, are intended to assess respondents' perspectives, attitudes, and experiences in critical areas such as financial management, time management, resource management, and technical infrastructure.

3.1.1 Questionnaire Survey

Table 1 shows the structure of a research for questionnaires survey divided into three sections, each focused on different facets of building maintenance management in Malaysian higher education institutions. Section A responds to the respondent's demographic information and provides important background data for analysis. Section B focuses on the major challenges in building maintenance management, establishing the framework for comprehending the problems. Section C explores further, analyzing these challenges in order to gain insight into their root causes, consequences, and possible solutions.

Table 1: Questionnaire's section

Section	Title
A	Respondent’s Demographic
B	Identify the major challenges faced in building maintenance management at Malaysian higher education institutions.
C	Analyze the challenges faced in building maintenance management at Malaysian higher education institutions

3.2 Sampling

This study employed a random sampling technique, in which respondents were selected randomly from a defined population of maintenance-related personnel at three selected UiTM campuses which are *Tapah, Puncak Alam*, and *Dengkil*. This method was adopted to reduce

sampling bias and enhance the generalizability of findings across a wider population of university facility staff. By giving each eligible individual an equal chance of being selected, the study ensures a more objective representation of the maintenance management landscape within Malaysian higher education institutions. According to the Krejcie and Morgan (1970) sample size determination table, the target population of 75 individuals yields a minimum recommended sample size of 63 respondents. The use of random sampling allowed the researcher to capture a diverse range of experiences and perspectives, providing a more balanced view of the challenges encountered in building maintenance operations.

3.3 Data Analysis Techniques

The data acquired for this study was analyzed using descriptive statistical techniques to provide an entire understanding of the structured questionnaire replies. Core statistical indicators such as mean, standard deviation, and frequency distribution were used to synthesize demographic data and uncover common patterns, difficulties, and attitudes about building maintenance challenges in Malaysian higher education institutions. The research was carried out using the Statistical Package for the Social Sciences (SPSS), which enabled precise data processing, effective classification, and the creation of visual outputs such as tables and charts. These results emphasized the most often reported difficulties, the level of satisfaction with current maintenance processes, and suggestions for improvement. The descriptive analysis was critical in converting raw survey data into useful insights, allowing for the formulation of relevant and practical suggestions to improve the efficiency and sustainability of maintenance management procedures in the government's institutions.

4.0 RESULTS AND DISCUSSION

The Results and Discussion section provides a complete analysis of the data gathered using structured questionnaires, with the objective of identifying and evaluating the significant challenges in building maintenance management at Malaysian higher education institutions. This section uses descriptive statistics including mean and standard deviation to analyze respondents' impressions of four main variables which are financial management, operation and maintenance, inventory management, and communication.

4.1 Descriptive Statistics for Demographic

Table 2: Descriptive Statistics for Position

Position

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Facility Manager	11	17.5	17.5	17.5
	Engineer	9	14.3	14.3	31.7
	Assistant Engineer	16	25.4	25.4	57.1
	Supervisor	7	11.1	11.1	68.3
	Technician	19	30.2	30.2	98.4
	Finance	1	1.6	1.6	100.0
	Total	63	100.0	100.0	

Table 2 shows an important proportion of respondents from technical front jobs directly involved in building maintenance, as the table demonstrates that the majority of responders are Technicians (30.2%) and Assistant Engineers (25.4%). Engineers (14.3%) and facility managers (17.5%) come next, indicating strategic and managerial engagement. Just 1.6% of

responders are from the finance sector, compared to 11.1% who are supervisors. With a significant number of contributions from technical employees, this distribution indicates that the research includes viewpoints from both the operational and administrative levels.

Table 3: Descriptive Statistics for Types of Institutions

Types of Institutions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	UiTM Kampus Puncak Alam	20	31.7	31.7	31.7
	UiTM Dengkil	17	27.0	27.0	58.7
	UiTM Tapah	26	41.3	41.3	100.0
	Total	63	100.0	100.0	

According to the data, UiTM Tapah represents 41.3% of the total respondents, followed by UiTM Puncak Alam (31.7%) and UiTM Dengkil (27%). A well-rounded yet localized understanding of building maintenance procedures in Malaysian higher education institutions is suggested by this distribution, which shows balanced involvement across the three main UiTM campuses with slightly higher representation from Tapah.

Table 4: Descriptive Statistics for Types of Maintenance

Types of Maintenance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Preventive maintenance	10	15.9	15.9	15.9
	Corrective maintenance	16	25.4	25.4	41.3
	Predictive maintenance	16	25.4	25.4	66.7
	All of above	21	33.3	33.3	100.0
	Total	63	100.0	100.0	

According to the statistics, 33.3% of respondents use all three forms of maintenance preventive, corrective, and predictive showing that they take a thorough approach to facility maintenance. The equal prevalence of predictive and corrective maintenance (25.4% each) indicates a heavy dependence on condition-based and reactive approaches. There may be room for improvement in proactive maintenance planning across institutions, as preventive maintenance alone is the least used (15.9%).

Level of Involvement in the Industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Direct involvement (planning/ implementing maintenance work)	29	46.0	46.0	46.0
	Direct involvement (planning/ implementing maintenance work), and indirect involvement (support/ monitor/ approve)	33	52.4	52.4	98.4
	Not directly involved but aware of maintenance issues	1	1.6	1.6	100.0
	Total	63	100.0	100.0	

Table 5: Descriptive Statistics for Level of Involvement in the Industry

The majority of respondents (52.4%) are directly involved in the planning and execution of maintenance as well as indirectly through support or approval positions, according to the

statistics. A further 46% work only in direct maintenance. This shows a high level of industry participation since almost all respondents have hands-on or decision-making responsibilities in maintenance operations. The sample's relevance and dependability in reflecting operational viewpoints are demonstrated by the fact that just 1.6% of respondents indicated it was aware of maintenance difficulties without having direct participation.

4.2 Descriptive Statistics for Variables

Descriptive Statistics were also calculated using SPSS for each construct in order to identify their level of mean among respondents. The secretive statistics were also calculated for each item and variable to analyze their among the respondents. The three levels of categories according to the mean consists of low (1.00 – 2.33), medium (2.34 – 3.67) and high (3.68 – 5.00). (Indiran et al., 2020)

Table 6: Descriptive Statistics for Financial Management (N= 63)

Financial Management (Mean= 3.7434 Std. Deviation= 0.75421)				
Items	N	Mean	Std. Deviation	Level
B1.1 Decisions regarding procurement of spare parts or maintenance systems consider long-term value, not just initial costs.	63	3.87	1.114	High
B1.2 Delays in financial approvals frequently results in the postponement of critical maintenance work	63	4.21	.953	High
B1.3 Weak financial governance undermines the effectiveness of facility maintenance operations.	63	3.86	.998	High
B1.4 The maintenance budget approval process is swift and efficient.	63	3.29	1.325	Medium
B1.5 Maintenance expenditures are assessed based on operational effectiveness and long-term cost savings (life-cycle costing).	63	3.68	1.090	High
B1.6 The annual maintenance allocation is sufficient to meet essential facility requirements.	63	3.56	1.280	Medium
Valid N (listwise)	63			

Table 6 presents the findings of respondents on financial challenges in building maintenance. The total mean score of 3.7434 indicates a significant level of concerns. The item with the highest mean (4.21) emphasizes the importance of financial approval delays, which frequently result in the delay of important maintenance work. Similarly, is concerned regarding poor management of finances (mean = 3.86) and long-term value consideration in procurement (mean = 3.87) received high ratings. However, budget approval efficiency (mean = 3.29) and the adequacy of yearly appropriations (mean = 3.56) obtained considerably lower ratings and were classified as medium level, indicating room for improvement. The standard deviation of 0.75421 implies moderate fluctuation in replies, indicating that concern continues among respondents.

Table 7: Descriptive Statistics for Operation and Maintenance (N=63)

Operation and Maintenance (Mean=3.7460 Std. Deviation= .77127				
Items	N	Mean	Std. Deviation	Level
B2.1 Preventive maintenance is carried out consistently and systematically.	63	3.54	1.105	Medium

B2.2 Maintenance tasks are prioritised based on the severity and risk of potential failures.	63	3.94	1.030	High
B2.3 Periodic maintenance activities are executed punctually as scheduled.	63	3.60	1.115	Medium
B2.4 The adoption of technologies such as the Computerised Maintenance Management System (CMMS) has enhanced work efficiency.	63	3.84	1.019	High
B2.5 Digital technologies are employed across all aspects of maintenance operations.	63	3.57	1.254	Medium
B2.6 The institution possesses a well-defined and structured long-term maintenance strategy.	63	3.98	.959	Medium
Valid N (listwise)	63			

Table 7 shows the mean score for Operations and Maintenance is 3.7460, suggesting a high perceived challenge level. Items such as risk-based maintenance priority (mean = 3.94) and the presence of a defined long-term maintenance strategy (mean = 3.98) were evaluated highly, indicating beneficial improvements in strategic planning. However, the consistency of preventative maintenance (mean = 3.54) and the use of digital technology (mean = 3.57) obtained middling scores, indicating gaps in consistent implementation. The standard deviation of 0.77127 indicates moderate variability in responder opinions, notably on the use of digital solutions and preventative procedures.

Table 8: Descriptive Statistics for Inventory Management (N=63)

Inventory Management (Mean =3.7751 Std.Deviation = .76678)				
Items	N	Mean	Std. Deviation	Level
B3.1 Maintenance storage facilities are well-organised and fulfil logistical requirements.	63	3.73	1.139	High
B3.2 The existing inventory system is user-friendly and easily accessible.	63	3.81	1.014	High
B3.3 Delays in restocking spare parts disrupt academic and administrative functions.	63	3.75	.999	High
B3.4 Manual inventory systems lead to slower response times in spare part procurement.	63	3.95	.991	High
B3. 5 Spare parts inventory audits are conducted regularly and systematically.	63	3.48	1.134	Medium
B3.6 The utilisation of QR/barcode scanning technology in inventory management is still limited, leading to inaccuracies in stock data.	63	3.94	1.014	High
Valid N (listwise)	63			

Table 8 indicates that Inventory Management is another significant cause of be concerned; with a mean of 3.7751 and a standard deviation of 0.76678, indicating a high level of perceived difficulty and generally consistent responses. High-rated topics include the influence of manual systems on reaction times (mean = 3.95), the restricted usage of QR/barcode scanning (mean = 3.94), and the usability of existing inventory methods (mean = 3.81). These findings show that, while inventory systems operate, there are major technical and operational gaps. Only the item on routine stock audits (mean = 3.48) obtained a medium rating, indicating that stock auditing processes are inconsistent or underemphasized.

Table 9 Descriptive Statistics for Communication (N= 63)

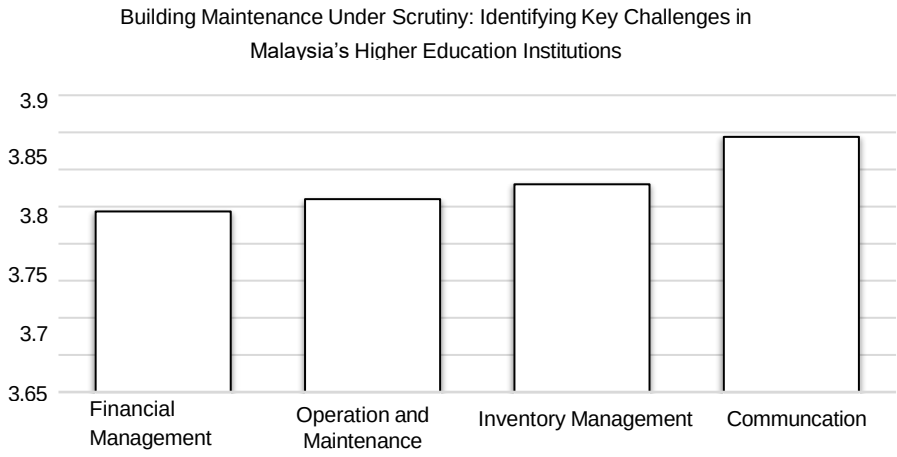
Communication (Mean = 3.8439 Std. Deviation = .78567				
Items	N	Mean	Std. Deviation	Level
B4.1 Two-way communication between facility users and maintenance teams is effective.	63	3.94	1.076	High
B4.2 Digital applications or platforms are optimally used to disseminate maintenance-related information.	63	3.76	.979	High
B4.3 Feedback from users is incorporated to enhance maintenance processes.	63	3.76	1.073	High
B4.4 Inaccurate transmission of technical information negatively impacts maintenance outcomes.	63	4.00	.933	High
B4.5 Centralised system exists for real-time tracking of maintenance request statuses.	63	3.70	1.102	High
B4.6 All damage reports are properly documented and filed.	63	3.90	1.058	High
Valid N (listwise)	63			

Table 9 shows communication recorded the highest mean score of 3.8439, indicating it is perceived as the most pressing challenge. The standard deviation of 0.78567 indicates a considerable variance of viewpoints while confirming a largely shared concern. High-rated elements include the negative impact of incorrect technical knowledge (mean = 4.00), two-way contact between users and maintenance teams (mean = 3.94), and good recording of damage reports (mean = 3.90). Even areas like the utilization of digital platforms (mean = 3.76) and feedback inclusion (mean = 3.76) received good ratings, highlighting the overall communication hurdles that impede maintenance efficiency.

Table 10: Descriptive Statistics of Research Findings

Variables	Mean	Std. Deviation	Level
Financial Management	3.7434	.75421	High
Operation and Maintenance	3.7460	.77127	High
Inventory Management	3.7751	.76678	High
Communication	3.8439	.78567	High

Table 10 shows the descriptive statistics for the four primary variables addressed in the present research which is Financial Management, Operation and Maintenance, Inventory Management, and Communication. The table for each variable contains the mean, standard deviation, and a level classification based on the average score. The mean scores, which range from 3.7434 for Financial Management to 3.8439 for Communication, show that respondents noticed all four categories as extremely critical issues. The standard deviations, which range from 0.75421 to 0.78567, indicate a reasonable level of consistency in responds throughout individuals. Particularly, all variables are assigned a "High" rating, emphasizing their relevance in the context of the research. Overall, the descriptive statistics give an accurate indication regarding how respondents observe each variable, emphasizing their perceived importance while also demonstrating regular patterns of response. This table provides an adequate framework for more research and educated findings.



Graph 1 Mean for Variables (N= 63)

The bar chart depicts the mean levels of challenges in building maintenance at Malaysian higher education institutions, with an emphasis on four main categories: financial management, operation and maintenance, inventory management, and communication. Communication is the most major challenge, with an average score of within 3.84, showing widespread challenges with information flow and coordination. Inventory Management and Operation and Maintenance have comparable average grades (≈3.78 and 3.76), but Financial Management is significantly lower (≈3.74) but still demands consideration. Overall, the findings identify communication as the most critical area for development, providing significant insights for stakeholders looking to increase maintenance efficiency and effectiveness at academic institutions.

5.0 CONCLUSION

Based on the findings of this research, it is clear that building maintenance management in Malaysian higher education institutions confronts a variety of obstacles, notably in the areas of communication, inventory management, operational procedures, and financial control. The findings, based on structured responses from 63 facility-related personnel across UiTM campuses, clearly show that communication barriers such as ineffective information flow, a lack of real-time tracking, and insufficient feedback systems are the most significant impediments to efficient maintenance operations. Although financial management had the lowest mean of the four aspects, it nonetheless highlights serious difficulties, such as budget approval delays and inadequate allocation. Inventory and operational issues, such as the use of manual processes and uneven preventative maintenance methods, worsen inefficiency. Overall, the results obtained highlight the critical necessity for a proactive, technology-integrated, and well coordinated maintenance approach that incorporates enhanced communication platforms, digital inventory systems, organized operational planning, and transparent finance procedures. By addressing these critical areas, universities may improve infrastructure dependability, save long-term expenses, and create an accepting and sustainable academic environment.

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Challenges in Implementing Digital Technologies for Maintenance Practices at Stadium

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ABSTRACT
The adoption of digital technologies in stadium maintenance presents both opportunities and challenges. This study aims to suggest potential strategies to address the challenges of digitalization for maintenance practices at stadiums. The research focuses on identifying key issues faced by facility management staff in implementing advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics. There are several challenges, including high initial costs, aging infrastructure and equipment, limitations in maintenance and technical support, and resistance to change. A qualitative research method was employed, using semi-structured interviews with 9 facility management staff at three prominent stadiums: Stadium Malawati in Shah Alam, Sultan Suleiman Stadium in Klang, and Stadium Panasonic in Shah Alam. The findings reveal that high costs, outdated infrastructure, limited technical expertise, and resistance to change are key barriers to adopting digital technologies in stadium maintenance. These challenges hinder the effective implementation of digital technologies in stadium maintenance practices. The outcome of this study may assist facility management in developing strategic solutions to improve maintenance operations through digital transformation.

Keywords: digital, technologies ,maintenance, practices, strategy

1.0 INTRODUCTION

The Internet of Things (IoT), artificial intelligence (AI), and big data analytics are some of the cutting-edge technologies that are changing conventional maintenance paradigms in modern stadiums, which are situated at an important of technological innovation and operational management. These new technologies have the potential to completely change how stadium infrastructure is managed by allowing real-time tracking, planned maintenance, and the best use of resources (Chen & Dai, 2024).

1.1 Research Background
Advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics have created significant opportunities to improve the management and maintenance of stadiums (Chen & Dai ,2024). These digital technologies have the potential to enhance operational efficiency and optimize the overall use of resources within stadium facilities. By adopting these modern tools, stadium management can achieve better monitoring, faster decision-making, and more effective maintenance practices.

However, the shift toward digital transformation faces several challenges. Wang (2024) stated one major issue is the cultural resistance within traditional sports organizations, where management often relies on outdated methods and is hesitant to adopt new technologies. This reluctance can slow down the digitalization process. Despite these obstacles, digital transformation in stadium maintenance can provide long-term benefits, such as reducing repair costs, extending the lifespan of infrastructure, and improving the overall performance and utilization of stadium assets.

One significant for digitalisation in stadium maintenance is financial ones. Studies show that digital transformation provides major long-term financial benefits including reduced repair process costs, longer resource lifespans, and best use of assets (Watanabe et al., 2018). Using modern technology allows stadiums to apply predictive maintenance plans that find possible infrastructure problems before they become major repairs. Internet of Things (IoT) sensors.

1.2 Problem Statement

The situation of Shah Alam Stadium in Selangor highlights the severe issues that ageing sports facilities face in the current day. The stadium, which used to be an emblem of sports success and could hold an amazing 80,000 people, has been ignored and poorly maintained for years, and it will eventually have to be demolished down. This situation is a great example of the bigger problems that stadium managers all over the world have to deal with the terrible effects of missing inspections, not updating facilities, and not spending enough on maintaining infrastructure. The stadium's decline highlights the critical necessity for proactive maintenance methods and ongoing technological adaption in sporting venues. Moreover ,the age of the current infrastructure greatly causes the natural difficulty of stadium modernisation. Most stadiums were constructed more than 35 years ago, and their architecture and technology were very different at the time. This makes it hard to add new technology to old stadiums (van Heck et al., 2021). The architectural and structural constraints of these ageing sites provide significant obstacles for using modern digital technologies. Often lacking the required electrical systems, physical layouts, and technical frameworks to smoothly combine modern IoT devices, advanced connection solutions, and intelligent monitoring systems, legacy infrastructure.

2.0 LITERATURE REVIEW

The purpose of the main literature review was to distinguish what has been studied from what needs to be learned. The literature review has been linked to its effect. Among the main topics of literature reviews were the challenge of digitalization in stadium maintenance.

2.1 High Initial Costs

High initial costs are a major challenge in stadium maintenance, primarily due to limited budgets and rising operational expenses. Insufficient financial resources and the absence of long-term maintenance planning often lead to delays in repairing and replacing outdated equipment and facilities. In many cases, sports facilities suffer from poor maintenance, increasing the need for large-scale repairs, replacements, or even the construction of new facilities (Harun et al.,2017). Additionally, facility management often struggles with financial and operational limitations, which further restricts their ability to maintain stadiums effectively. A lack of proper maintenance planning, insufficient knowledge in facility management, and poor maintenance quality also contribute to higher operational costs and reduce the overall efficiency of stadium operations.

The financial aspects of stadium upkeep provide complicated challenges that greatly affect operational sustainability and infrastructure durability. Edelin Hussein et.al (2023) emphasises that financial limits provide two primary challenges such as inadequate funding for regular maintenance and rising operating costs. This financial constraint establishes an unstable process in which immediate cost-cutting measures frequently result in more costly and comprehensive issues in the future. The impacts of these limitations beyond mere maintenance, influencing the whole operating framework of sporting facilities.

2.2 Aging infrastructure and equipment

As these structures and tools grow older, maintenance becomes increasingly problematic, leading to higher costs and operational inefficiencies. The lifespan of sports equipment is also shortening, resulting in more frequent replacements and a higher likelihood of malfunctions (Yang & Chen,2016). Additionally, damaged facilities and failing equipment indirectly drive up operating expenses while reducing potential revenue for organizations. These issues collectively underscore the financial and logistical burdens posed by outdated infrastructure and equipment in the sports sector.

Equipment failure and facility damage. Infrastructure that is falling apart creates a negative feedback loop like equipment failures and facility damage lead to increased operating costs, which in turn reduce revenue generation potential (Harun et al.,2017). This decrease in income makes it even harder to pay for repairs and improvements, which keeps things getting worse. The research emphasizes that old equipment does not just affect how the stadium works physically, but also has big effects on the facility's ability to stay in business.

2.3 Maintenance and Technical Support

Maintenance and technical support within stadiums and sports facilities, particularly due to a shortage of skilled personnel. The lack of trained maintenance staff leads to inefficiencies, delayed repairs, and a heavy dependence on external contractors for specialized work. Additionally, the absence of professionals with management or sports management expertise hinders the overall quality of facility administration. Maintenance teams often focus only on basic housekeeping and routine tasks due to insufficient manpower, which increases workloads, lowers motivation, and limits progress. Furthermore, the lack of technical competence acts as a barrier to adopting digital advancements, further restricting operational improvements in these facilities (Kans ,2019).

Lack of skilled repair workers in Malaysian stadiums is a big problem that needs to be fixed (Edelin Hussein et al.,2023).This problem shows up in a number of ways, including less efficient maintenance, longer repair times, and a greater need to hire outsource contractors for specialised maintenance jobs. Using outsource contractors not only increases operating costs but also makes it more difficult to handle urgent maintenance issues because scheduling and coordinating with third-party service providers adds another level of complexity to maintenance tasks. This shows how a facility's inability to keep things running at their best can be greatly affected by a lack of in-house knowledge.

2.4 Resistance to change

Resistance to change within sports organizations, particularly due to traditional and outdated management mindsets. Many conventional organizations struggle to adopt new technologies and digital transformations, clinging to old-fashioned operational methods instead (Wang, 2024). However, innovation, knowledge, and added value are crucial for staying competitive in today's rapidly evolving sports industry. Organizations that fail to adapt to digital advancements risk falling behind, as modernization plays a key role in driving efficiency and long-term success.

The rapidly evolving technological landscape further complicates implementation efforts. Sports organizations must continuously adapt to changes including digitization to maintain competitive advantage (Dasic,2023).For stadium maintenance specifically, this means navigating an increasingly complex ecosystem of Internet of Things (IoT) sensors, predictive maintenance software, and integrated facility management systems. The technical complexity

of these solutions requires specialized knowledge that many traditional maintenance teams lack.

3.0 METHODOLOGY

Research methods and approaches used from the initial stages of research to the analysis stage to obtain the data and information needed for the research results. The method used by the researchers in this study refers to the method used by social science researchers to identify effective communication. Discussion at each stage of the research method allows the researcher to reflect on the research process. In the first phase of the study, data collection began by reading books, published articles, and websites to understand the topic or problem that we wanted to investigate. Based on the identified problem, the researcher develops several research questions. After the questions were asked, several objectives of the study were set to make the study more focused. A conceptual framework is developed to easily explain the overall concept of the study.

3.1 Research Philosophy

The research onion gives a structured process for determining appropriate methodologies. The researcher adopts this framework by using Saunders' model which has six key layers such as philosophy, approach, methodological choice, strategy, time horizons, and techniques and procedures. Following this model ensures a comprehensive methodology to gather information and answer the research questions.

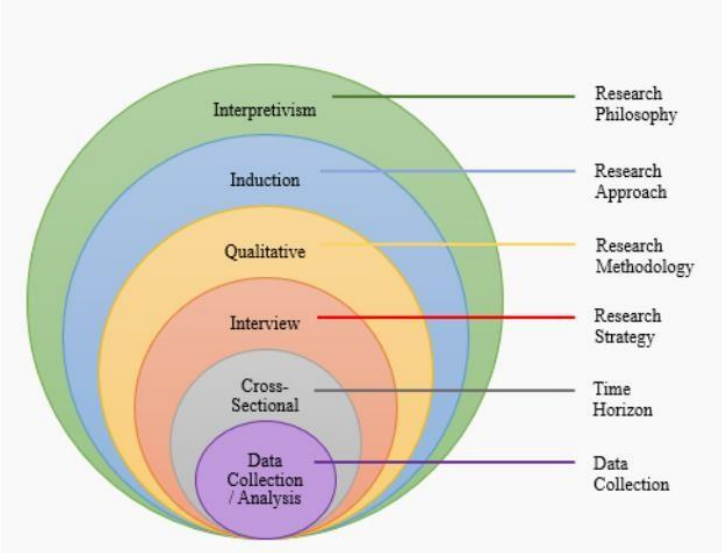

Figure 1:The research onion, proposed by Saunders et al. (2016)

3.2 Research Approach

The study aims to suggest a digitalization strategy for stadium maintenance. It will use an inductive approach, employing semi-structured interviews as the data collection method. This method allows for a flexible and exploratory analysis of the challenges of digitalization in maintaining stadiums. The study will follow a qualitative research strategy with a cross sectional time horizon, capturing diverse perspectives at a specific point in time. This approach will help in understanding the nuances of digitalization in stadium maintenance.

3.3 Research Design

The semi-structured interviews be used as the data collection tool for this research. Qualitative

research approach, which involves collecting non-numerical data to explore participants' experiences, perspectives, and meanings in depth. Based on the design of Maxwell (2012), the research question of this study can be considered as a central point. The five elements of purpose, conceptual framework, research question of the study, method, and validity can all answer the research question of the study. (Refer figure 1) This component relates to conceptual frameworks and research methods. This is because the purpose of this study is to create a conceptual framework and at the same time to determine appropriate methods of selecting research information and answer research questions. Validity is related to the research objectives, conceptual framework, methods, and questions. All components must be verified through validation with experts and used thematic analysis for the analysis the research.

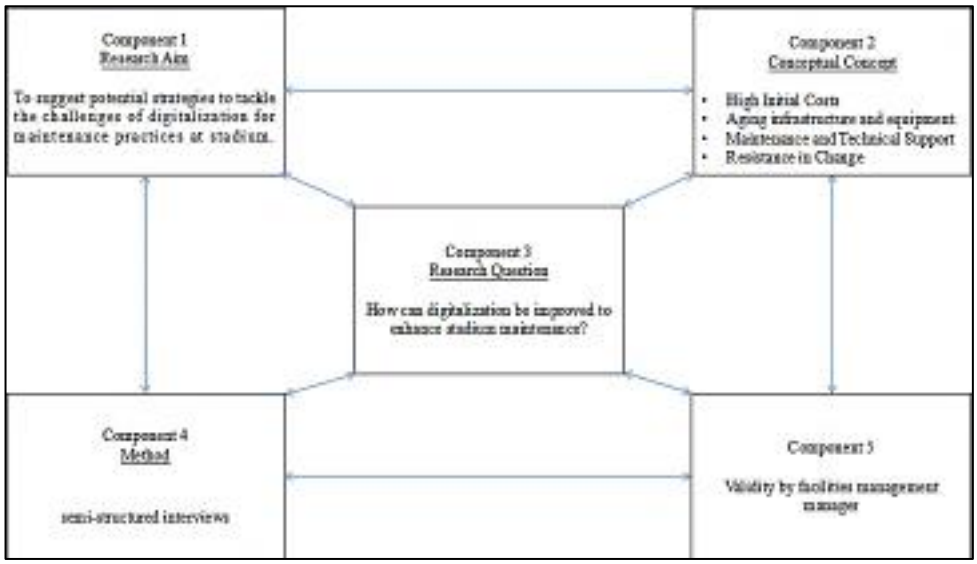

Figure 2 :Research Design

This study aims to recommend to suggest digitalization strategy for maintenance in the stadium. Figure 2 shows the conceptual framework presents the format of the research and provides guidance on the objectives to be achieved throughout the research process. This conceptual framework outlines four major challenges faced in the implementation of digital technologies for stadium maintenance. These include high initial costs, which hinder investment in smart systems; aging infrastructure and equipment, which are often incompatible with modern technologies; maintenance and technical support**,** reflecting a shortage of skilled personnel and resources; and resistance to change, where staff prefer traditional methods over new digital solutions. The diagram below is the conceptual framework for this study, in which three constructs will be used to collect data from respondents using qualitative methods.

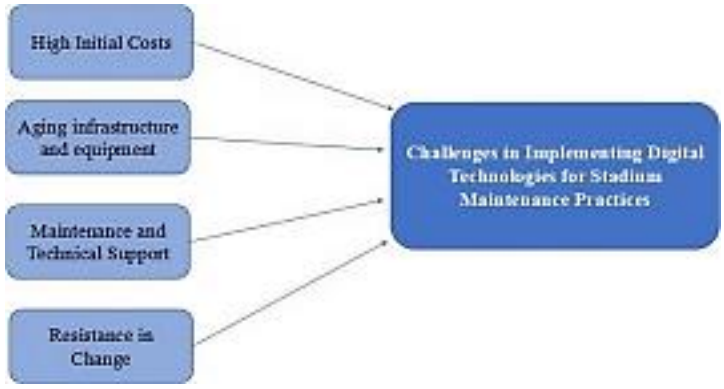

Figure 3: Conceptual Framework

The research questions are designed to ensure that the aims and objectives of this study are met This study was conducted to answer the following questions:

i. How do maintenance staff experience the challenges associated with maintaining the stadium?

ii. Why are there significant challenge to implementing digitalization in stadium maintenance?

iii. How can digitalization be improved to enhance stadium maintenance?

This study uses a qualitative research approach**,** specifically through semi-structured interview sessions**.** The interviews will be conducted with both middle management and first line management personnel who are directly involved in managing the service desk**,** where user complaints are recorded into the system**.** In total, nine individuals from the facilities management (FM**)** level will be interviewed. To ensure the validity of the interview questions, the questionnaire will be reviewed and validated by a Facilities Management Manager who has over 13 years of experience in the FM industry. This step is crucial to ensure that the questions are relevant, clear, and aligned with industry practices.

3.4 Population and Sample

Purposive sampling is a non-probability sampling technique commonly used in qualitative research, where participants are deliberately selected based on specific characteristics or knowledge relevant to the research objectives. This method ensures that the data collected is rich, detailed, and directly applicable to the study In this study, a total of nine participants were selected using purposive sampling, a technique suitable for qualitative research that focuses on individuals with relevant knowledge and experience. The participants were selected from three stadiums located in Selangor**:** Stadium Malawati**,** Stadium Panasonic**,** and Stadium Klang. Each stadium contributed three participants from different roles and departments, as outlined below:

1. Stadium A – Stadium Malawati, Darul Ehsan Facilities Management
Participant 1**:** Head of Engineering Department
Participant 2**:** Executive, Engineering Department
Participant 3**:** Administrative Staff, Engineering Department

2. Stadium B – Stadium Panasonic, Kompleks Sukan dan Belia Negeri
Selangor Participant 1**:** Executive, Operation Department

Participant 2**:** Technician, Operation Department
Participant 3**:** Administrative Staff, Operation Department

3. Stadium C – Stadium Klang, Majlis Bandaraya Diraja Klang
Participant 1: Head of Landscape Department
Participant 2: Executive, Landscape Department
Participant 3: Administrative Staff, Landscape Department

4.0 RESULTS AND DISCUSSION

The interview results directly address the research objectives and key variables related to the challenges in implementing digital technologies for maintenance practices at stadiums. The interview questionnaire was structured into three sections: Section A (Participant Demographics), Section B (To identify and analyze the challenges faced by stadium management in implementing digital technologies for maintenance practices), and Section C (To propose potential strategies to overcome the challenges of digitalization in stadium maintenance practices).

4.1 Finding and Analysis

4.1.1. Research Objectives

1: Identify the challenges faced by stadium management. The interviews revealed several challenges in implementing digital technologies for maintenance practices at the stadiums. Most participants indicated that the high initial cost is a major barrier. This is largely because Stadium Malawati**,** Stadium Panasonic, and Stadium Klang are owned by the state government but managed by separate entities**.** For example, Stadium Malawati **is** managed by Darul Ehsan Facilities Management**,** Stadium Panasonic **is** managed by the Perbadanan Stadium Malaysia (PSM)**,** a statutory body under the Ministry of Youth and Sports (KBS)**,** and Stadium Klang is under the management of the Klang Royal City Council (Majlis Bandaraya Diraja Klang)**.**As a result, any budget allocation must first be approved by the state government. Other critical challenges such as aging infrastructure and equipment, the need for technical support, and resistance to change are often overlooked. This is because the management companies are only responsible for the day-to-day upkeep of the stadiums, while major repairs and long-term decisions remain under the authority of the state government.

4.1.2. Research Objectives

2: Analyze the challenges faced by stadium management.

4.1.2.1 High Initial Costs

High initial costs are a significant barrier because implementing digital technologies requires a dedicated and substantial budget allocation. This issue was highlighted by several participants (P1, P2, P3, P4, P5, P7), who stated that the existing maintenance budget is already insufficient, let alone accommodating the additional costs of digital technology implementation. For example, P1 explained that high initial costs are a result of tight budget constraints. Each year, a specific budget is allocated for stadium maintenance, which is divided into two categories: Civil works (RM50,000) and Mechanical & Electrical (M&E) maintenance (RM35,000). If there are no remaining funds in Quarter 3 (Q3), the team is forced to reallocate funds from either the Civil or M&E category, depending on which has a surplus. Participants(P6,P8,P9) expressed concern that adopting digital technologies would require a large upfront investment, which is difficult to justify given the limited resources and the aging

condition of the infrastructure. Furthermore, addressing technical issues often involves additional costs to meet client expectations and ensure satisfaction, adding further strain to the already limited budget.

4.1.2.2 Aging Infrastructure and Equipment

Due to aging infrastructure, the most common problems faced at the stadium include roof damage and water leakage, particularly in the toilet areas. Participants (P1, P2, P4, and P5)stated that users often complain about leaking toilets, which are a recurring issue. Participants (P3 and P6) mentioned that roof leaks frequently occur during events, and because the stadium is old, the management often resorts to outsourcing temporary solutions, such as installing canvas covers to prevent further water intrusion. According to P8, vandalism has also contributed to damage, resulting in broken seating and structural wear that now requires major repairs. Meanwhile, (P7 and P9) reported that exposure to heavy rain has caused the stadium gates to rust and the walls to fade and peel, giving the facility a neglected and deteriorated appearance.

4.1.2.3 Maintenance and Technical Support

Participant (P7) stated that there is a sufficient number of trained maintenance staff, especially those with more than three years of experience. This view was supported by Participants (P8 and P9), who noted that experienced staff are already familiar with the field and their job scope. However, (P1,P2,and P3)emphasized the need to send all technicians for training sessions to further enhance their technical skills and keep up with current maintenance standards. Participants (P5 and P6) agreed that while there are enough trained staff, there is still a need to improve soft skills, particularly in technical reporting. For example, P4 highlighted that maintenance staff should be equipped with both hard and soft skills. Technicians should not only be able to carry out physical repairs, such as plumbing, but also be capable of preparing technical reports for their supervisors. This would help middle management communicate more effectively with top management about the overall status of repair work orders.

4.1.2.4 Resistance in Change

Participants (P1, P5, and P7) observed that experienced staff tend to prefer traditional manual processes and show little interest in adopting digital solutions. This resistance is largely due to familiarity with existing methods and discomfort with unfamiliar technologies. On the other hand, Participants (P2, P3, P8, and P9) emphasized the importance of offering support and technical assistance during the transition to digital systems. They believe that providing guidance and hands-on support can ease the process and increase staff acceptance. Meanwhile, Participants (P4 and P6) highlighted the need to consider the cost and budget implications when implementing new technologies. They pointed out that financial constraints and limited funding are key reasons why management and staff may hesitate to embrace digital transformation.

4.1.3. Research Objectives 3: Strategies and Recommendation

4.1.3.1 Low cost digital solutions

Participants (P1, P2, and P3) suggested purchasing low-cost digital maintenance management systems or modules. These systems can help track, schedule, and document maintenance activities more effectively, offering a simple yet practical step toward digitalization without major investment Participants (P4, P5, and P6) recommended investing in advanced equipment that can streamline and speed up maintenance tasks. While the initial cost may be moderate, these tools can improve efficiency and reduce long-term labour costs. Meanwhile, Participants suggested several cost-effective approaches to support digital transformation in stadium maintenance without placing a heavy financial burden on the management. Participants (P7,

P8, and P9) proposed outsourcing certain maintenance services, such as cleaning and planned preventive maintenance (PPM), to external service providers. This approach can reduce internal workload and operational costs while maintaining service quality.

4.1.3.2 Modernize aging infrastructure without significant costs

Participants (P1, P2, and P3) suggested engaging outsourced service providers through lump sum contracts that include both repair works and planned preventive maintenance (PPM)**.** However, such arrangements must first be approved by the state government**,** as the stadiums are government owned. Participants (P4, P5, and P6) recommended using high quality, durable materials during repair and upgrade works. This approach can reduce the frequency of emergency maintenance and lower long-term maintenance costs. Meanwhile, Participants (P7, P8, and P9) proposed low-cost cosmetic upgrades such as repainting stadium gates with black oil-based paint to prevent rust and enhance appearance, and applying varnish to plastic seats to restore their shine and protect them from wear and tear.

4.1.3.3Training programs for upskilling maintenance staff

Participants (P1, P2, and P3) recommended sending staff for certified technical training programs such as those offered by CIDB (Construction Industry Development Board) and NIOSH (National Institute of Occupational Safety and Health). These certifications help staff improve their technical competency and ensure compliance with industry standards. Participants (P4, P5, and P6) emphasized the need for soft skill training, particularly in areas such as communication, teamwork, and documentation, which are essential for efficient maintenance coordination and reporting. Participants (P7, P8, and P9) stressed the importance of safety certifications, noting that long-serving staff often do not have valid safety cards. Ensuring that all maintenance personnel are certified in workplace safety is crucial to reducing risks and improving overall operations

4.1.3.4 Staff are comfortable using advanced digital tools

Participants (P1, P2, and P3) suggested organizing hands-on training sessions that include manual guides and live demonstrations. These sessions allow maintenance staff to understand the functionality and operation of digital tools more effectively. Participants (P4, P5, and P6) proposed leveraging in-house engineers to teach and support maintenance staff in using advanced digital technologies. This peer-to-peer approach can ease the learning curve and foster better collaboration. Participants (P7, P8, and P9) recommended incorporating digital tools into routine maintenance tasks, such as using daily checklists and digital logs to record data. This not only improves accuracy but also helps staff build familiarity with digital reporting and monitoring systems over time.

4.0 CONCLUSION

The study reveals that stadium management faces significant challenges in adopting digital technologies for maintenance, including high initial costs, aging infrastructure, staff resistance to change, and the need for technical support. To address these issues, a phased implementation approach is recommended, starting with cost-effective digital solutions for high-priority areas like roof and toilet maintenance. Staff training and change management initiatives should be introduced to build confidence in new systems, while securing management buy-in through demonstrated ROI from pilot projects is crucial. Additionally, exploring funding partnerships and adopting a hybrid model that integrates digital tools with existing manual processes can ease the transition. These strategies aim to modernize maintenance practices, reduce reactive costs, and improve long-term efficiency while accommodating the stadium's operational constraints.

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Challenges of Smart Technology Implementation in Facility Management Organizations in Klang Valley

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ABSTRACT

Previous research has focused on integrating smart technologies for Facility Management, but there is a lack of studies on challenges, barriers and solutions in FM. The main challenges faced by Facility Management Organizations (FMOs) in adopting and operating smart technologies in Klang Valley, Malaysia, necessitate a focused investigation. This study aims to provide recommendations for enhancing the effective operation of these smart technologies within facility management practices. The significance of this research lies in its potential contribution to industry players, Facility Management Organizations, and governmental bodies such as the Public Works Department (JKR) and the Construction Industry Development Board (CIDB) by outlining strategies for successful smart technologies implementation. Employing a quantitative method, this research gathers and analyzes numerical data sample size of 118 respondents from Facility Management Organizations (FMOs) located in Klang Valley to identify key challenges and potential solutions using survey questionnaire The main findings highlight all challenges are very significant but human resource issues are the critical one. Consequently, the study concludes with several recommendations aimed at improving the adoption and operation of smart technologies in facility management for future use and research.

Keywords: challenges, facility, management, smart, technology

1.0 INTRODUCTION

1.1 Research Background

The incorporation of advanced technologies, including artificial intelligence (AI), data analytics, and the Internet of Things (IoT), is swiftly revolutionising the real estate and facilities management industries. With the expansion of metropolitan regions such as the Klang Valley, the integration of smart technologies in building operations has become essential for enhancing energy efficiency, operational performance, and occupant satisfaction. The integration of these technologies facilitates ongoing surveillance and modification of environmental factors, including temperature, illumination, and air quality, thereby enhancing overall efficiency and user experience (CIDB, 2024). Facility management is today regarded as a function that unifies individuals, processes, and technology to elevate the quality of life for building occupants while enhancing operational efficiency (IFMA, 2024). The effective application and administration of smart technologies in facility management necessitate addressing four principal challenges: financial limitations, technical difficulties, human resource constraints, and managerial inefficiencies (Hauashd, et al. 2020). These constraints impede the efficient operation of smart technologies while elevating operational costs and maintenance responsibilities for site management.

1.2 Smart Technology Effectiveness

Smart Technologies encompass the utilisation of artificial intelligence and data science methodologies, including machine learning and big data, to establish cognitive awareness in objects. This is facilitated by information and communication technologies such as the

Internet of Things (IoT) (Chung, 2021).While effectiveness defines as the degree to which objectives are achieved, characterised as 'doing the right things' (Erlendsson, 2002). Smart technologies full potential is found in their capacity to increase this efficacy by offering data driven insights that result in wiser choices and more effective actions. Previous study stated that there are various way to enhanced Facility Management organization performance, one of it in terms of technology adoption. Implementing advanced management systems and predictive maintenance tools, funding training initiatives, and encouraging proactive stakeholder participation in order to improve Facility Management (Ling & Husain, 2024). A number of technologies, including artificial intelligence (AI), the Internet of Things (IoT), and building information modelling (BIM), were introduced to aid in facilities management and enhance decision-making. However, data management and the real-world application of these technologies continue to provide difficulties for facility managers (Olimat, et al. 2023).

1.3 Financial

Smart technologies necessitate significant initial investments and continuous operational expenses, potentially burdening the financial resources of several organisations, especially in swiftly rising urban areas such as Malaysia (Anathan, et al. 2023). has been recognised as a significant obstacle to the effective deployment of smart technologies. Financial limitations, especially regarding budget allocation, significantly influence the efficacy and long-term viability of implementing sophisticated technology in building management. Resolving these financial difficulties necessitates a diverse strategy. Coordination among stakeholders, such as real estate developers, building owners, and facilities management teams, is crucial for efficiently managing financial restrictions (Baharetha, et al. 2024). Cost optimisation in building maintenance is a vital component in tackling financial issues. The necessity for efficient financial management solutions to optimise maintenance expenditures while preserving the operational efficacy of the building (Hauashd, et al. 2020).

1.4 Management

Smart technologies can overwhelm users and cause inefficiencies and dissatisfaction in their adoption and use if they are not designed with user-friendliness in mind. They also frequently necessitate a thorough understanding of the underlying systems and data flows (Kittley Davies, 2020).The effectiveness of integrating smart technology is contingent upon continually addressing the growing demands and preferences of users. The necessity of perpetually assessing and incorporating user requirements into the smart building process to ensure that the end result meets the expectations of stakeholders, especially clients and tenants (Baharetha, et al. 2024). A major problem in this approach is addressing user opposition to the adoption of smart technologies. Resistance from users or clients towards adopting new technologies or worries over their integration might adversely affect the effectiveness of the implementation smart technologies (Latifah, et al. 2020). It is imperative to involve users from the outset and continuously throughout the process to mitigate these worries, deliver explicit information, and cultivate trust in the newly implemented technologies. This proactive involvement facilitates smoother acceptance and improves the overall performance. Communication is a vital and essential component of any organisation in order to foster cooperation in the workplace, which affects organisational performance and decision-making,. Effective communication has also been shown to affect the performance of organisations. The performance of an organisation usually suffers when there is ineffective communication (Musheke & Phiri, 2021).

1.5 Human Resource

Human resources define by oxford dictionary is the employees of a company or organisation, who are considered a valuable resource in terms of their skills and abilities. An essential component of human resource management is training and development. Employers must hire competent workers in order to improve performance, and workers who possess the necessary knowledge and abilities will be more productive (Karim, et al., 2019). A major difficulty encountered by Facility Management (FM) teams in Malaysia is the absence of ongoing professional development opportunities. The lack of uniform training programs impedes FM teams' capacity to adopt and execute contemporary FM methods efficiently (Ling & Husain, 2024). The effective adoption and management of smart technologies systems in buildings significantly rely on a proficient staff adept at integrating, managing, and troubleshooting the technologies (Anathan, et al. 2023). Other than that, facilities management professionals should be encouraged to receive training and upskilling so they can integrate and adapt new technologies and tools into their current processes and activities and avoid falling behind in this 4IR era (Okoro & Musonda, 2019). By engaging in ongoing professional development, FM workers can bridge the existing skills gap and secure the enduring success and sustainability of smart building operations.

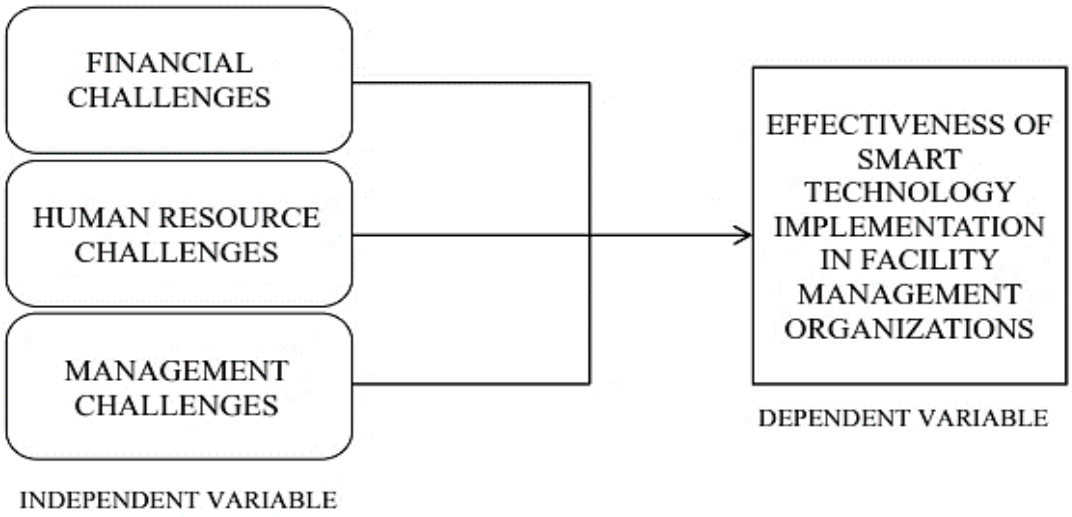

Figure 1: Conceptual Framework

To conduct this study, a quantitative method was used. Quantitative research is the process of using numerical values obtained from observations to characterise and explain the processes that the observations may reflect on (Taherdoost, 2022). A survey questionnaire was distributed to facility management organizations employees located in the Klang Valley. Based on Krejcie and Morgan table, sample size is 118 people. There are 6 sections in the questionnaire. Section A is about the demographic profile of the respondents, followed by section B, C, D and E discuss the item regarding the variables and section F regarding suggestions from respondent. The target respondent are chosen using purposive sampling method, employees of facility management organizations at executive level such as facility managers, facility executive, maintenance engineers which these group have direct involvement with smart technology implementation process. Purposive sampling is an intentional selection of sources based on their ability to explain a certain theme, idea, or event (Robinson, 2023). Data was analyzed using descriptive and inferential techniques including frequency analysis and mean comparisons. These techniques enable to identify the most influential challenges affecting smart technology implementation in facility management

organizations to formulate recommendations for enhancing the effective operation of these smart technologies within facility management practices.

3.0 RESULTS AND DISCUSSION

The data gathered from respondents was analysed using the Statistical Package for Social Science (SPSS). Descriptive statistics and intricate inferential statistical methods are among the statistical activities that may be carried out with the data management and analysis tool SPSS. A frequency analysis and data cleaning were done to ensure that the data were correctly entered and labelled. descriptive statistical data, such as percentages, means, and frequencies.

3.1 Descriptive Statistics for Variable

Descriptive statistics were calculated for each item to determine the respondents' level of each variable and item. The mean (average) are divided into three (3) levels, which is low (1.00-2.33), medium (2.34-3.66), and high (3.67-5.00) (Abdul Ghafar 2003).

Table 1 : Descriptive Statistics for Variables (N=118)

Variables	Mean	Std. Deviation	Level
FINANCIAL	3.93	.77230	High
MANAGEMENT	3.93	.76814	High
HUMANRESOURCE	3.98	.71401	High

The descriptive analysis results in Table 1 show that all three independent variables recorded high mean scores. The Financial Challenges variable obtained a mean of Mean = 3.93, followed closely by Management Challenges (Mean = 3.93) and Human Resource Challenges (Mean = 3.98). These results indicate that the respondents generally perceived a high level of challenges across financial, management, and human resource aspects in implementing smart technology in facility management organizations.

Table 2 : Descriptive Statistics for Strategies for Improvement (N=118,Mean=3.99)

Items	Mean	SD	Level
1. Outsourcing certain technical tasks can overcome staff skill limitations	4.07	1.044	High
2. Early involvement of end-users in technology selection increases project success.	4.03	1.025	High
3. Continuous feedback from users helps improve the use of smart systems.	4.03	1.037	High

4. Conducting pilot projects helps reduce risks before full implementation.	4.03	1.109	High
5. Increasing staff training will enhance smart technology adoption.	4.02	1.078	High
6. Allocating a specific budget for smart innovation would improve implementation.	3.99	1.128	High
7. Developing a smart technology roadmap improves planning.	3.99	1.106	High
8. Cross-functional collaboration is essential for smart technology integration.	3.98	1.054	High
9. Leadership support is crucial for driving technology transformation.	3.94	1.056	High
10.Providing incentives (e.g., bonuses, recognition) encourages adoption.	3.89	1.138	High

Table 2 shows descriptive statistics of Strategies for Improvements. Overall, all of the items are at high level (Mean=3.99). Among all, item "Outsourcing certain technical tasks can overcome staff skill limitations" is the highest, (Mean=4.07). Followed by 3 items that have the same mean which is (Mean=4.03), "Early involvement of end-users in technology selection increases project success", "Continuous feedback from users helps improve the use of smart systems", "Conducting pilot projects helps reduce risks before full implementation".

3.2 Correlation and Regression

Using the Pearson correlation coefficient, a correlation analysis was conducted to examine the relationship between the effectiveness of smart technology implementation and the challenges of finance, management, and human resources. The direction and intensity of a relationship between variables are measured by the correlation coefficient (r). The correlation's strength is determined by the r value, which varies between +1.00 and -1.00 (Chua YP, 2013).

Table 3 : Size and Strength for Correlation

Size of Correlation	Strength of Correlation
0.91 until 1.00 or -0.91 until -1.00	Very Strong
0.71 until 0.90 or -0.71 until -0.90	Strong
0.51 until 0.70 or -0.51 until -0.70	Moderate
0.31 until 0.50 or -0.31 until -0.50	Weak
0.01 until 0.30 or -0.01 until -0.30	Very Weak
0.00	No Correlation

Table 4 : Relationship between challenges and effectiveness of smart technology implementation

		Correlations			
		Financial	Management	Human Resource	Effectiveness
Financial	Pearson Correlation	1	.904**	.886**	.893**
	Sig. (2-tailed)		.000	.000	.000
	N	118	118	118	118
Management	Pearson Correlation	.904**	1	.904**	.891**
	Sig. (2-tailed)	.000		.000	.000
	N	118	118	118	118
Human Resource	Pearson Correlation	.886**	.904**	1	.908**
	Sig. (2-tailed)	.000	.000		.000
	N	118	118	118	118
Effectiveness	Pearson Correlation	.893**	.891**	.908**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	118	118	118	118

**. Correlation is significant at the 0.01 level (2-tailed).

H1: There is a significant positive relationship between financial challenges and effectiveness of smart technology implementation.

H2: There is a significant positive relationship between management challenges and effectiveness of smart technology implementation.

H3: There is a significant positive relationship between human resource challenges and effectiveness of smart technology implementation.

Based on table 4, the relationship between financial challenges and effectiveness of smart technology implementation is strong (r=0.893). The relationship is also significant at the level of 0.01. Therefore, we accept the hypothesis that there is a significant positive relationship between financial challenges and effectiveness of smart technology implementation. The variable management challenges shows that there is positive relationship with effectiveness of smart technology implementation where the it is strong (r=0.891) and at the level of 0.01. Therefore we accept the hypothesis that there is a significant positive relationship between management challenges and effectiveness of smart technology implementation. Other than that, the relationship between human resource challenges and effectiveness of smart technology implementation also shows a strong relationship (r=0.908). The relationship is also significant at the level of 0.01. Therefore, we accept that there is a significant positive relationship between human resource challenges and effectiveness of smart technology implementation.

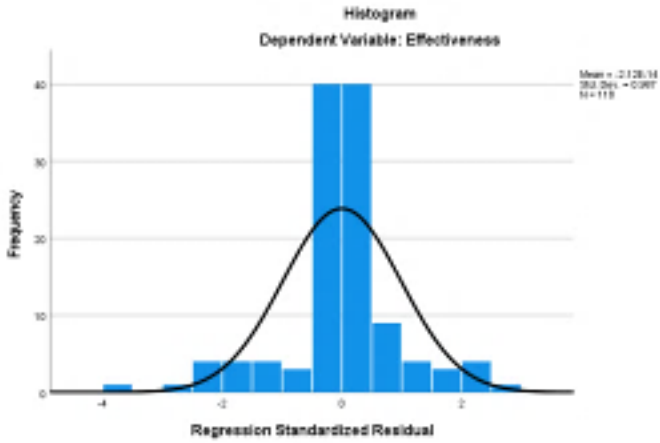

Figure 2 : Histogram of variables and Effectiveness of Smart Technology Implementation

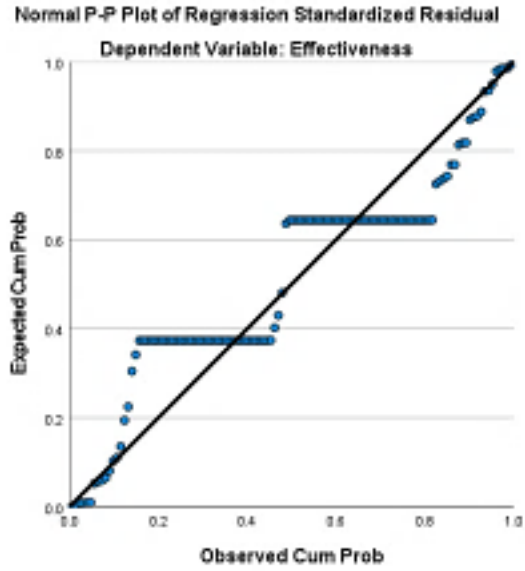

Figure 3 : Linear of variables and Effectiveness of Smart Technology Implementation

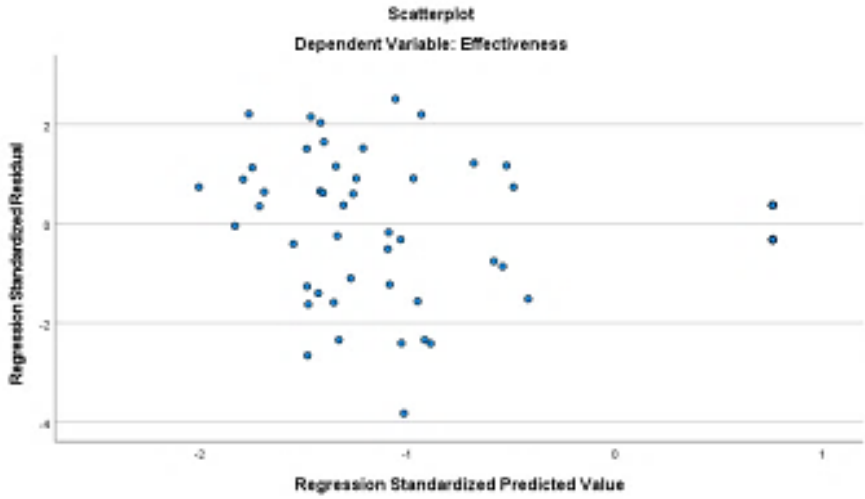

Figure 4 : Scatterplot of Variables and Effectiveness of Smart Technology Implementation

4.0 CONCLUSION

From the results, Facility Management Organizations (FMOs) in Klang Valley face high levels of challenges in implementing smart technologies, human resource issues are the most critical (Mean=3.98), followed by financial (Mean=3.93) and management challenges (Mean=3.93). Constraint in human resource such as lack of technical skill, training and resistant to change significantly impede effective implementation. Financial challenges such as high initial cost and delayed approvals entangled adoption efforts. Management issues such as poor communication, lack of strategic direction and limited stakeholder engagement also contribute to disorganization. These findings underline the need for effective strategies for the success of integrating smart technologies in facility management. Outsourcing to overcome skill limitations are the best strategies to overcome the human resources related issues. Early involvement of user and collecting feedback from the user helps to strategize in order for smart technology implementation success and improve systems efficiency.

ACKNOWLEDGMENT

First and foremost, I would want to give gratitude and appreciation to God, the Almighty, for His many gifts that enabled me to successfully finish my research methodology paper throughout my assessment job. I am fortunate to have received this direction and aid along with the completion of this research paper, as the success and end of this paper required a great deal of help from many individuals. Additionally, I would like to sincerely thank Madam Nor Hazlin Binti Md Gharip and Sr. Norezan binti Asmangi from the Department of Civil Engineering at Polytechnic Sultan Salahuddin Abdul Aziz Shah for their graciousness in granting me personal space when needed and providing guidance when needed. I am grateful for my supervisors' encouragement, friendship, support, and advice. Not to mention, my family members' kind cooperation and encouragement have been invaluable to me in pursuing this endeavour. Thank you to all of them, friends, and family. I would like to express my sincere thanks to all the people and organisations whose help and contributions have been crucial in developing and putting into practice the research methodology for this study. They have been invaluable in helping this project succeed with their advice, knowledge, and cooperation My sincere thanks. Thank you very much.

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Customer Satisfaction Toward The Rehabilitation Facilities Provided By Government Hospital

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ABSTRACT
This study aims to investigate customer satisfaction with the rehabilitation facilities provided by government hospital. Rehabilitation services in Malaysia are unevenly distributed, with a concentration in urban areas, limiting access for rural populations. Standardization of care could improve outcomes, ensure consistent quality, and enhance patient satisfaction across different centers. There is limited data on the long-term effectiveness of rehabilitation programs in Malaysia. A qualitative research method is used in this study. The sampling size is among 66 patients in three government hospital in Negeri Sembilan, Malaysia. Using survey questionnaires distributed to 66 patients in three government Hospital in Negeri Sembilan, data will be gathered on element physical environment, support services and medical equipment. From the required 66 respondent, has completed the survey in questionnaires given by google form. Statistical analysis using IBM SPSS Software Version 27.0 will reveal patterns between these variables and competencies. The goal are key factors influencing patient satisfaction in rehabilitation in health care

Keywords: Customer, Satisfaction, Rehabilitation, Facilities, Hospital.

1.0 INTRODUCTION

1.1 Research Background
Hospital rehabilitation centres are essential to patient care because they offer specialised assistance to patients recuperating from diseases, traumas, or operations. The ultimate objective of these institutions is to help patients regain their independence and improve their general quality of life by restoring or improving any compromised physical, mental, or cognitive abilities. Rehabilitation centres have a variety of roles, including helping patients recover, managing pain, and fostering functional independence through specialised treatments and interventions. Along with providing emotional and psychological assistance to treat mental health issues related to physical limitations, they are also essential in teaching patients and carers how to effectively manage their conditions.

1.2 Aim & Research Objectives

1.2.1 Aim
Propose the key factors influencing patient satisfaction in rehabilitation in health care centres and develop strategies for enhancing overall service quality.

1.2.2 Research Objectives
- To identify facility components that impact patient satisfaction in the rehabilitation centre.
- To analyse the effectiveness of current facilities in rehabilitation centre.
- To recommend improvements to facilities based on identified feedback.

2.0 LITERATURE REVIEW

This study examines customer satisfaction with gymnasium rehabilitation facilities in Malaysian hospitals, a crucial measure of the quality and effectiveness of services provided. Understanding patients' perspectives on rehabilitation services is essential for identifying areas for improvement, ensuring better health outcomes, and enhancing the overall patient experience.

By providing areas with exercise equipment, therapeutic supplies, and open spaces for movement therapy, gyms play a vital role in rehabilitation. According to studies, patients undergoing rehabilitation benefit from organised exercise in a gym environment in terms of their cardiovascular health, muscular strength, flexibility, and mental health (Smith & Brown, 2020). Furthermore, motivation and adherence to rehabilitation programs are improved by having access to gym facilities (Doe et al., 2019).

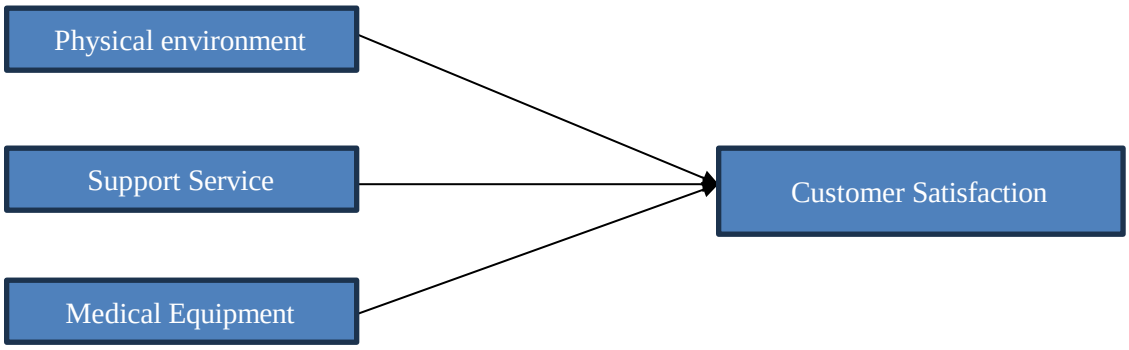

Figure 1 Conceptual Framework

3.0 METHODOLOGY

The quantitative method is a systematic research approach that involves collecting and analyzing numerical data to identify patterns, test hypotheses, and explain phenomena. It is widely applied in fields such as social sciences, economics, education, and healthcare to provide objective and generalizable findings. This method often employs structured tools like surveys, questionnaires, or standardized tests to ensure consistency in data collection. Quantitative research typically follows a deductive approach, starting with a theory or hypothesis and using data to confirm or refute it. Its emphasis on measurement, objectivity, and replicability makes it suitable for large-scale studies aiming to produce reliable and comparable results (Creswell, 2014).

A research instrument refers to the tool or device used by researchers to collect, measure, and analyze data related to a research topic. In the context of a questionnaire, the research instrument is the actual set of questions designed to gather information from respondents. It serves as a structured method for obtaining consistent and comparable data across a sample population. A questionnaire, it serves as a standardized instrument consisting of a series of questions designed to gather information from respondents in a consistent manner. In qualitative research, questionnaires often include open-ended questions that encourage detailed, reflective responses, allowing participants to express their experiences, perceptions, and attitudes in their own word questionnaire is critical it must be aligned with the research objectives, written in clear accessible language, and structured to facilitate the depth and relevance of responses. To ensure the

instrument's effectiveness, researchers often conduct pilot testing to identify and correct any ambiguities or biases in the questions. (Creswell, 2014; Rattray & Jones, 2007).

4.0 RESULTS AND DISCUSSION

4.1 Descriptive Statistics (quantitative data)

The descriptive statistics were calculated for each item and variable to investigate their ranking among the respondents.

Table 1: descriptive statistics for Physical Environment (N=66)

NO	Variable (Physical environment)	Mean	SD	Rank
1	This rehabilitation center is clean and organized.	3.91	.907	High
2	Therapy equipment is in good condition and sufficient.	3.95	.885	High
3	Waiting areas and treatment rooms are comfortable and conducive.	3.91	.890	High
4	Facilities such as toilets, elevators, and wheelchair parking are easily accessible.	4.00	.928	High

Table 1 shows the mean and standard deviation for the variable “Physical Environment” the result indicates a moderately high level of good physical environment.
(M=4.00, SD= 0.928)

Table 2: Descriptive Statistics for Support Services (N=66)

NO	Variable (Physical environment)	Mean	SD	Rank
1	Staff responded quickly to patient needs.	4.02	.936	High
2	Complaints or problems were addressed promptly.	3.82	1.021	High
3	Follow-up was done after treatment if necessary.	4.05	.919	High
4	I was given the opportunity to ask questions about the treatment.	3.92	.900	High

Table 2 shows the mean and standard deviation for the variable “Support Services” the result indicates a moderately high level of good support services.
(M=4.05, SD = 0.919)

Table 3: Descriptive Statistics for Medical Equipment (N=66)

NO	Variable (Physical environment)	Mean	SD	Rank
1	The necessary medical equipment is always available during treatment.	3.97	.976	High
2	The equipment used functions well without any problems.	3.95	.867	High
3	The technology used at the rehabilitation centre is modern and appropriate.	3.97	.894	High

Table 3 shows the mean and standard deviation for the variable "Medical Equipment" the result indicates a moderately high level of medical equipment uses.

4.1.1 Mean for each variable

The descriptive statistics were analyzed for three main categories of improvement to the Customer satisfaction toward the rehabilitation facilities provided by the government hospital. The average means were calculated from the variable to determine which practices impact most the government facilities as seen in table 5 below:

Table 5: Mean for variable (N=66)

No	Variable	Mean	SD	Rank
1	Physical Environment	4.00	0.928	High
2	Support Services	4.05	0.919	High
3	Medical Equipment	3.97	0.976	High

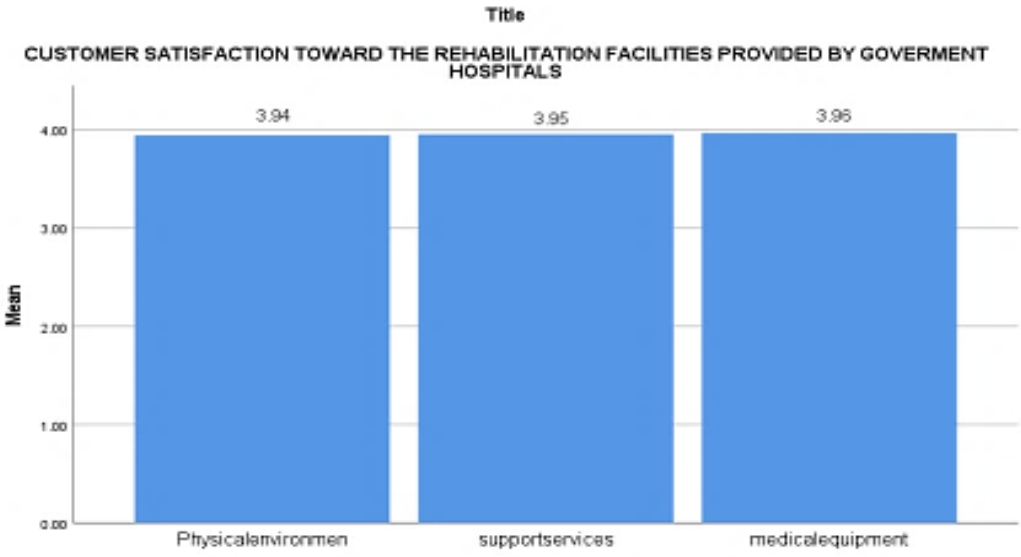

Figure3: Graph mean for Variable (N=66)

5.0 CONCLUSION

From the analysis of quantitative data obtained the customer satisfaction for facilities provided at the three scope of research has given a good understanding. Although the ratings for these aspects were still positive, they were relatively lower compared to other items. Therefore, efforts to enhance communication and responsiveness in patient interactions could further improve the overall satisfaction levels. In conclusion, while the facilities and environment are well-regarded, strengthening patient engagement and support services could lead to even better outcomes.

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Effectiveness of Energy Efficiency Strategies in Office Buildings at Cyberjaya

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ABSTRACT
This study aims to evaluate the effectiveness of energy efficiency strategies implemented in office buildings in Cyberjaya, Malaysia, a region characterized by significant energy consumption and greenhouse gas emissions due to its tropical climate. Challenges in optimizing energy efficiency in office buildings such as limited data, inconsistent application of measures, and varying effectiveness in Malaysia's tropical climate are still underexplored. Although some energy-efficient designs and retrofitting projects have shown promise, their actual impact on reducing energy use and improving performance remains unclear. This is further complicated by the lack of localized studies in Cyberjaya, a major urban area with many office buildings. Understanding these factors is essential for developing more effective, tailored strategies for similar urban environments in Malaysia. The purpose of this study is to propose strategies for improving energy efficiency in office buildings at Cyberjaya. This study used qualitative methodology and semi-structured interview protocol has been held. A purposive sampling method are used in this study which are the respondent selected among expertise personal only. There are two (2) office buildings and four (4) persons in charge in those buildings were involved in this study which is a Facilities Manager and an Energy Manager from each office buildings are chosen. The qualitative data will be analyze by using content analysis.

Keywords: effectiveness, energy, efficiency, building, strategies

1.0 INTRODUCTION

1.1 Research Background
Energy use in buildings is a major global concern, as this sector accounts for 30–40% of total energy consumption and contributes heavily to greenhouse gas emissions. Office buildings, in particular, use a lot of energy due to constant lighting, HVAC systems, and office equipment. In tropical countries like Malaysia, the hot and humid weather increases the need for cooling, making energy efficiency even more important (Hafez et al., 2023; Jemat et al., 2023).

Improving energy efficiency helps the environment and also reduces operational costs and improves energy security. Effective strategies include better building design, use of renewable energy, energy audits, government incentives, and new technologies (Ilham et al., 2022; Jemat et al., 2023).

Design features like natural ventilation, better building materials, and using daylight can lower cooling and lighting needs, which fits well in tropical climates (Hafez et al., 2023; Jemat et al., 2023). Solar panels also help by cutting down the use of fossil fuels (Ilham et al., 2022).Government policies like Malaysia's National Renewable Energy Policy and Energy Efficiency Master Plan support these efforts through incentives and regulations (Hafez et al., 2023; Jemat et al., 2023). New technology like smart HVAC, LED lighting, and building automation improves energy use and building performance (Hafez et al., 2023).

Still, some challenges remain, such as high initial costs, low awareness, and limited expertise. This research looks at how effective these strategies are in tropical office buildings and aims to create a practical guide for improving energy efficiency and sustainability. Although the

Malaysian government has introduced many policies to promote energy efficiency in buildings, there is still a big gap in how well these strategies are carried out and assessed, especially in fast-growing areas like Cyberjaya (Jemat et al., 2023; Zul Ilham et al., 2022). Challenges such as a lack of detailed data, inconsistent use of energy-saving methods, and the mixed results of different strategies in Malaysia's tropical climate are still not well studied (Jemat et al., 2023).

Even though some energy-efficient designs and retrofitting projects have been implemented, their actual effects on reducing energy use and improving building performance are not clearly understood (Jemat et al., 2023). This issue is made worse by the lack of local studies that look at how these strategies perform over time in Cyberjaya, which has many office buildings (Zul Ilham et al., 2022). Understanding these challenges is important for creating better, more suitable energy efficiency strategies not only for Cyberjaya but also for other similar cities in Malaysia (Jemat et al., 2023; Zul Ilham et al., 2022).

1.2 Aim and Research Objectives

The purpose of this study is to promote the effectiveness of energy efficiency strategies currently implemented in office buildings in Cyberjaya.

A few objectives have been developed to achieve the objective of the study and answer the research question:

i. To identify the factors contributing to the variation in effectiveness of energy efficiency strategies across different office buildings in Cyberjaya.

ii. To analyze the factors contributing to the variation in effectiveness of energy efficiency strategies across different office buildings in Cyberjaya.

iii. To enhance strategies for improving energy efficiency in office buildings in Cyberjaya.

2.0 LITERATURE REVIEW

Energy efficiency is a major global concern, especially in the construction industry, which uses a lot of energy and produces greenhouse gases. Office buildings are among the highest energy users due to constant use of HVAC systems, lighting, and equipment. In tropical countries like Malaysia, high cooling needs make energy-saving measures even more important. Improving energy efficiency in office buildings brings both environmental and economic benefits.

This study aims to address these issues by evaluating energy-saving techniques specifically for office buildings in tropical areas. It will explore the environmental, economic, and practical outcomes of methods like design improvements, renewable energy use, energy audits, and new technologies. The goal is to help develop scalable solutions that reduce energy use, improve performance, and support sustainable development in the building industry. Conceptual framework for this study as shown in Figure 1.

2.1 Effectiveness of Energy Efficiency Strategies in Office Buildings

Growing concerns about environmental sustainability, as well as rising energy consumption, have highlighted the necessity of energy efficiency methods in buildings, particularly in office buildings, which consume a substantial amount of energy. The task of improving energy efficiency is even more acute in tropical areas like Malaysia, where the climatic conditions need a lot of cooling energy. This literature review investigates the efficacy of energy efficiency

techniques adopted in office buildings, drawing on a wide range of research on design optimization, renewable energy integration, energy audits, government laws, and technology improvements (Kasim et al., 2016).

2.2 Building Design Optimization

Hafez et al. (2023) found that passive design solutions, including natural ventilation, enhanced thermal envelopes, and daylighting, may significantly reduce cooling and lighting energy needs. Similarly, in tropical climes, passive cooling using architectural features such as shade, optimized window locations, and reflecting materials is quite efficient. According to Jemat et al. (2023), passive design integrates natural energy sources like the sun and wind into building design to reduce energy demand for heating and cooling. These studies highlight the importance of building design in improving energy efficiency.

2.3 Renewable Energy Integration

Integrating renewable energy sources, particularly solar energy, is another efficient way to improve energy efficiency in office buildings. Malaysia's tropical environment provides enough sunshine, making solar energy a feasible option for reducing reliance on fossil fuels. According to Hafez et al. (2023), rooftop solar PV systems may significantly cut carbon emissions and improve energy efficiency in Malaysia's tropical environment discovered that solar panels and other renewable technologies, such as wind and biomass, may greatly reduce operating costs and contribute to sustainable building operations. The use of such renewable systems is consistent with worldwide initiatives to minimize greenhouse gas emissions while also increasing the energy performance of office buildings.

2.4 Energy Audits and Monitoring

Energy audits and ongoing monitoring are critical for detecting inefficiencies and ensuring that energy-saving solutions are implemented correctly. Conducting thorough energy audits enables building managers to identify places where energy is being wasted and take corrective action, such as retrofitting. According to Jemat et al. (2023), energy audits can identify inefficiencies in building systems, and retrofitting can result in energy savings of up to 20%. These audits are essential for not just detecting energy usage trends, but also verifying that retrofit actions, such as improving HVAC systems and lights, produce the expected savings.

2.5 Energy-Efficient Technologies

The utilization of sophisticated technology such as smart HVAC systems, LED lighting, and Building Automation Systems (BAS) is critical for optimizing energy use in office buildings. These technologies provide dynamic control over energy systems, lowering operational costs and enhancing building efficiency. According to Hafez et al. (2023), smart HVAC systems with LED lighting can improve energy efficiency and lower operational expenses in buildings. The use of smart technology provides greater control over energy usage, resulting in considerable operational savings and improved occupant comfort.

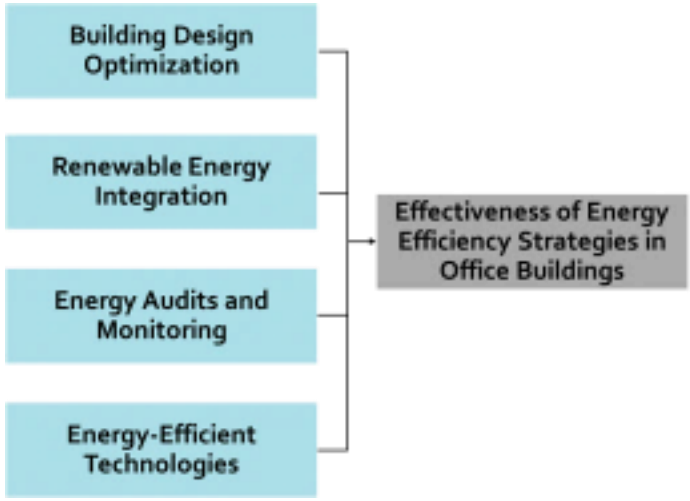

Figure 1 : Conceptual Framework

3.0 METHODOLOGY

This chapter explains the specific methods used in the study. The research uses a clear methodology to collect data effectively and achieve its goals. This methodology is important for developing and applying a framework that guides how data is gathered and how the study is analyzed. According to Creswell (2014), qualitative research is an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. Qualitative research is a method of inquiry that focuses on understanding human experiences, behaviours, and the meanings individuals or groups assign to social or human problems. It emphasizes gathering rich, in-depth insights through non-numerical data such as interviews, observations, and textual analysis. Qualitative research aims to explore complex phenomena from the perspective of the participants. A well-defined and properly applied method helps ensure smooth data collection. This chapter also covers data collection tools, the study population and sample, data analysis, and the overall research design. Research design for this study refer Figure 2.

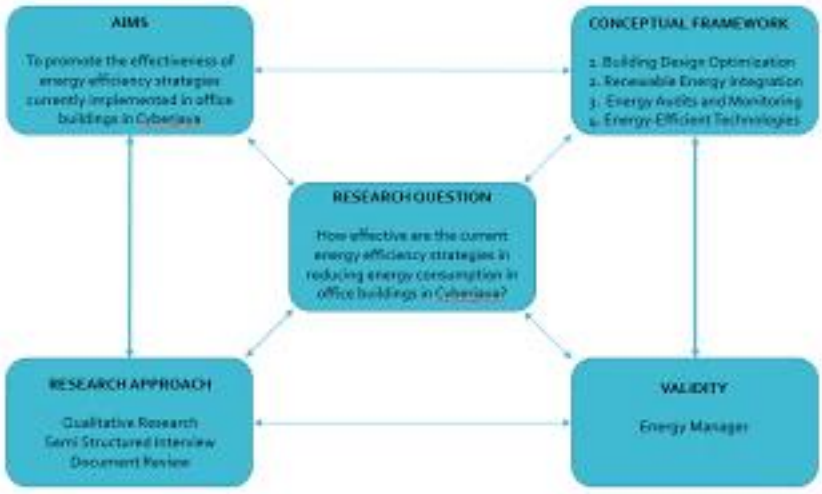

Figure 2 : Research Design (Source by Maxwell, 2013)

3.1 Research Instrument

The semi-structured interview protocol for this study is organized according to four key components identified in the conceptual framework, each representing a critical strategy contributing to the effectiveness of energy efficiency in office buildings.

The **first part** of the interview focuses on **Building Design Optimization**. This section aims to gather information on design strategies such as natural ventilation, daylighting, thermal insulation, and building orientation. Respondents will be asked about how these design features have been implemented and how they contribute to energy performance.

The **second part** explores **Renewable Energy Integration**. Questions in this section seek to understand the extent to which renewable energy sources, such as solar PV systems, have been adopted in office buildings. It also investigates challenges, incentives, and the perceived impact of renewable integration on energy use and sustainability goals.

The **third part** addresses **Energy Audits and Monitoring**. This part of the interview is designed to collect data on how energy performance is tracked and evaluated in office buildings. Respondents will be asked about the frequency of audits, the tools or systems used for monitoring, and how the data collected informs decision-making and improvements.

The **fourth part** focuses on **Energy-Efficient Technologies**. This includes questions about the use of modern technologies such as LED lighting, smart HVAC systems, and building automation systems (BAS). The aim is to assess how these technologies are used to improve energy efficiency and the perceived outcomes of their implementation.

Each part of the interview is structured to align with the study's framework, ensuring that the data collected directly supports an in-depth analysis of the effectiveness of energy efficiency strategies in office buildings.

3.2 Population and Sample

All the elements that the researcher is interested in, wants to design, and wants to generalise are together referred to as the population. The population consists of all the variables we are studying and trying to evaluate. The population would be staff from Facilities Management Company, Person in Charge from clients in these buildings:

i) Suruhanjaya Komunikasi dan Multimedia, Cyberjaya;
ii) Lembaga Hasil Dalam Negeri, Cyberjaya.

After determined the population, identify person in charge from the Facilities Management Company and clients from each buildings. Person in charge such as Facility Manager and Energy Manager from Facilities Management Company. Person in charge from clients is the person who is responsible to monitor Facilities Management Company contract. Proper selection ensures accurate data collection, considering feasibility and adjusting sampling methods as needed (Shukla, 2020).Sampling is the process of selecting a sample from a population, categorized into probability and non-probability sampling methods, based on research objectives. For this study sampling method is convenience sampling which is a non probable sampling method. The sample will target 1 to 3 person in charge in each building.

This study uses content analysis to examine the data collected from semi-structured interviews with Facilities Managers and Energy Managers from office buildings in Cyberjaya. The goal is

to identify common themes and ideas related to four main energy efficiency strategies: building design, renewable energy use, energy audits, and energy-saving technologies. After the interviews are transcribed, the responses will be organized and coded to find patterns that show how these strategies are applied and how effective they are. This process helps the researcher better understand real experiences and challenges in improving energy efficiency, and supports the development of practical suggestions for future improvements in office buildings.

4.0 RESULTS AND DISCUSSION

There are (4) participants were involve in this study. They are from Facilities Management Company from those buildings and building owner representative. According to Creswell, (2017), the range is 5-25 respondents are acceptable for qualitative research. However, for this research purpose, only four participants are involved due to expertise and in charge regarding energy management. Four participants who were involved in the study to ensure the validity and consistency of the data gathered.

4.1 Results for First and Second Objective

To identify and analyze the factors contributing to the variation in effectiveness of energy efficiency strategies across different office buildings in Cyberjaya.

4.1.1 Variable 1: Building Design optimization

The analysis emphasizes the integration of advanced infrastructure, notably Building Automation Systems (BAS), which streamline HVAC, lighting, and energy use for improved efficiency and centralized management. Strategic spatial planning enables flexible load management, particularly during non-peak hours, contributing to overall energy performance. However, maintaining occupant comfort while enhancing energy efficiency remains a challenge due to the building's size and diverse functions. Future improvements may include greater use of passive design strategies and more efficient space utilization to boost performance.

4.1.2 Variable 2 : Renewable Energy Integration

The current assessment reveals that the energy output from the existing solar panels is limited and highly dependent on weather conditions, falling short of initial performance expectations. Despite this, incorporating renewable sources such as solar PV presents a viable opportunity to reduce dependence on grid power and centralized cooling, ultimately cutting costs and emissions. Looking ahead, adopting a phased approach to expanding solar capacity and investigating additional renewable technologies could support the building's environmental and financial objectives.

4.1.3 Variable 3 : Energy Audits and Monitoring

The analysis highlights the importance of continuous monitoring through Building Automation Systems (BAS) and routine energy audits. These efforts support informed operational decisions in areas like load management and system efficiency. Advanced tools for energy profiling and consumption tracking provide detailed insights that facilitate timely interventions. This data driven approach empowers facility managers to implement effective strategies such as demand reduction programs and system tuning which collectively lead to improved energy performance and cost efficiency.

4.1.4 Variable 4 : Energy-Efficient Technologies

The report outlines the deployment of several energy-saving technologies, such as BAS-driven demand control, efficient lighting, and chilled water systems sourced from Gas District Cooling.

These implementations have led to measurable energy cost reductions, including savings of over 10% through optimized tariffs and load management. The synergy between automated controls and cooling efficiency contributes to lowering peak energy usage and operational expenses. Looking ahead, technology choices will depend on infrastructure compatibility, cost, and scalability, with future enhancements likely to focus on incorporating renewable sources and energy storage.

4.2 Result for Third Objective

Third Objective : To enhance strategies for improving energy efficiency in office buildings in Cyberjaya.

As Cyberjaya continues to grow as Malaysia's premier smart city, improving the energy performance of its office buildings is a crucial step toward sustainability. This report outlines practical, scalable strategies designed to enhance energy efficiency, reduce operational costs, and support national and local environmental goals.

4.2.1 Smarter Control Through Building Automation

Modernizing building control systems is one of the most effective ways to improve efficiency. By upgrading to advanced Building Automation Systems (BAS), facilities can manage HVAC, lighting, and other services more intelligently. These systems adjust operations based on occupancy and time of day, reducing unnecessary energy use during off-peak hours or in underutilized areas.

4.2.2 Solar Energy Expansion

Cyberjaya benefits from consistent solar exposure, making it ideal for solar power generation. Although initial solar panel outputs may be modest, phased solar PV installations can gradually reduce reliance on grid electricity. Integrating energy storage systems will further enhance reliability and enable power use even during low sunlight periods.

4.2.3 Efficient Lighting and Equipment

Switching to LED lighting paired with motion or daylight sensors is a straightforward upgrade that yields immediate energy savings. Likewise, equipping offices with energy-efficient appliances and devices reduces baseline power consumption and supports long-term sustainability goals.

4.2.4 Cooling System Optimization

Given Malaysia's warm climate, air conditioning is a significant energy driver. District Cooling systems already in place can be optimized by syncing them with BAS and installing variable speed drives and smart thermostats. These upgrades help align cooling output with real-time demand, reducing energy waste while maintaining comfort.

4.2.5 Continuous Monitoring and Regular Audits

Frequent energy audits and ongoing consumption monitoring are essential for identifying inefficiencies and guiding strategic decisions. Tools such as energy dashboards, smart meters, and load profiling enable building managers to take proactive measures to reduce waste and improve performance.

4.2.6 Passive Design and Space Utilization

Improving a building's physical design can significantly reduce energy usage. Strategies include:

i Enhancing natural lighting;
ii Installing better insulation and energy-efficient windows;
iii Using sun-shading devices to limit heat gain.

These measures help reduce reliance on mechanical systems and create more sustainable environments.

4.2.7 Encouraging Energy-Conscious Behaviour

Technical upgrades alone are not enough. Promoting a culture of energy awareness among tenants and staff leads to better energy habits. This can be achieved through:

i Awareness campaigns;
ii Clear operational policies;
iii Visible reminders and real-time feedback systems on energy use.

4.2.8 Summary

By implementing these strategies ranging from technological upgrades to behavioural shifts office buildings in Cyberjaya can achieve meaningful energy savings. These actions not only lower operating costs but also support Malaysia's broader climate and sustainability commitments. With careful planning and steady implementation, Cyberjaya can serve as a national model for energy-smart development.

CONCLUSION

As Cyberjaya cements its position as Malaysia's smart city, improving the energy performance of its office buildings is more than just a cost-saving move it's a step toward a more sustainable future. This study explores practical and scalable ways to enhance energy efficiency in commercial buildings by combining modern technology, thoughtful design, and smart management practices.

Through our analysis, we found that key systems like Building Automation Systems (BAS), energy-efficient lighting, and chilled water cooling already play a valuable role. However, their impact can be significantly amplified through strategic upgrades such as demand-based controls, expanded solar panel installations, and integration with battery storage. Regular energy audits and real-time monitoring were also highlighted as critical tools in identifying inefficiencies and guiding better decisions.

Beyond the technology, the study emphasizes the importance of design and behaviour. Passive features like improved insulation, natural ventilation, and daylighting not only reduce energy use but also create more comfortable workspaces. At the same time, cultivating a culture of energy awareness among tenants and staff can lead to consistent and lasting improvements.

What makes these strategies especially relevant to Cyberjaya is their adaptability. From existing high-tech buildings to newer developments, these solutions can be customized to fit different scales and budgets. Ultimately, by investing in smarter energy practices today, Cyberjaya has the opportunity to lead by example showing how modern urban spaces can be both high-performing and environmentally responsible.

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Employee Satisfaction Towards Indoor Environment Quality in Facility Management Organization

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ABSTRACT

Indoor Environmental Quality (IEQ) has emerged as a critical determinant of employee satisfaction, particularly within facility management organizations where indoor conditions significantly influence health, productivity, and overall workplace morale. IEQ are essential to creating healthy, productive, and satisfying work environments, particularly in organizations where employees spend the majority of their time indoors. This study aims to identify the key factors influencing employee satisfaction related to IEQ specifically focusing on indoor air quality, thermal comfort, and lighting within facility management settings. The research also proposes effective strategies to enhance IEQ and, in turn, improve overall employee satisfaction. A quantitative approach was adopted, utilizing a structured questionnaire featuring multiple-choice items, a five-point Likert scale, and open-ended questions for comprehensive data collection. Convenience sampling was used to gather responses from 67 employees across three BMES Maintenance SDN BHD branches in UiTM Seremban, UiTM Puncak Alam, and UiTM Rembau. Data analysis was conducted using SPSS software. Results indicated that indoor air quality had the highest impact on employee satisfaction, with effective ventilation systems rated most positively. Thermal comfort and lighting also influenced satisfaction, though issues such as inconsistent temperature control and limited access to natural daylight were identified as areas needing improvement. The findings underscore the importance of maintaining optimal IEQ through reliable air circulation, temperature regulation, and balanced lighting systems. Recommendations include enhancing workplace comfort through optimized space layout, improving air conditioning system and integrating automated technologies to monitor and adjust indoor conditions. This research offers actionable insights for improving workplace conditions and supports broader efforts to enhance employee well-being and organizational effectiveness in the Malaysian facility management sector.

Keywords: Employee, Satisfaction,Iindoor, Environment, Quality

1.0 INTRODUCTION

1.1 Research Background

Indoor Environmental Quality (IEQ) has emerged as a critical factor in workplace management due to its direct impact on employee well-being, health, and productivity, especially as workers spend up to 90% of their time indoors (Kim et al., 2022). Comprising elements such as thermal comfort, air quality, lighting, and acoustics, IEQ influences concentration, job satisfaction, and overall performance (Fissore et al., 2023). Poor IEQ conditions common in many developing countries due to outdated infrastructure can lead to respiratory issues, fatigue, and stress, ultimately hindering productivity and increasing absenteeism (Mansor, 2020). As such, facility management organizations play a vital role in enhancing IEQ to create healthier, more efficient, and more comfortable work environments.

1.2 Aim & Research Objectives

The aim of this research is to propose effective strategies for improving Indoor Environmental Quality (IEQ) to enhance employee satisfaction within facility management organizations. By

focusing on the workplace environment, this study seeks to address how improvements in IEQ can contribute to better employee well-being and organizational performance.

To achieve the aim of this research and to address the research question, the following objectives have been establish:

a) To identify the factor that influences employees satisfaction towards indoor environment quality (indoor air quality, thermal comfort and lighting) in facility management organization.

b) To analyze the factor that influences employees satisfaction towards indoor environment quality (indoor air quality, thermal comfort and lighting) in facility management organization.

c) To propose recommendations for improving indoor environment quality to enhance employees satisfaction in facility management organization.

2.0 LITERATURE REVIEW

Indoor Environmental Quality (IEQ) is a multifaceted concept encompassing factors such as air quality, thermal comfort, lighting, and noise levels, all of which play a crucial role in influencing employee health, well-being, and productivity (Noor & Ding, 2020). Given that people spend a substantial amount of time indoors, maintaining high IEQ is essential, particularly in office settings, where it has been shown to directly affect employee satisfaction (Abdulaali et al., 2024). Poor indoor air quality (IAQ), often caused by inadequate ventilation and indoor pollutants such as volatile organic compounds and particulate matter, can lead to health issues like respiratory problems and Sick Building Syndrome (Öz & Ergönül, 2016; Mujeebu, 2019). To prevent this, standards like those set by ASHRAE recommend maintaining CO_2 levels below specific thresholds to ensure adequate ventilation and minimize health risks (Kumar et al., 2023; Ehelepola & Thilakarathna, 2024). Thermal comfort, influenced by both environmental and physiological factors such as air temperature, humidity, clothing, and personal health, also significantly impacts workplace performance and satisfaction (Mujeebu, 2019; Ameen et al., 2023). Lighting, particularly a balanced integration of natural and artificial sources, affects visual comfort and task performance, and can further influence mood and energy efficiency (Fakhari et al., 2021). Employee satisfaction, a key determinant of workplace morale and productivity, is closely linked to these environmental conditions and can be enhanced by improving working conditions, offering training, and providing opportunities for autonomy and advancement (Shapnil, 2019; Waihenya, 2019). Together, these elements form a holistic approach to designing office environments that support both organizational success and employee well being. Figure 1 shows the conceptual framework in this study.

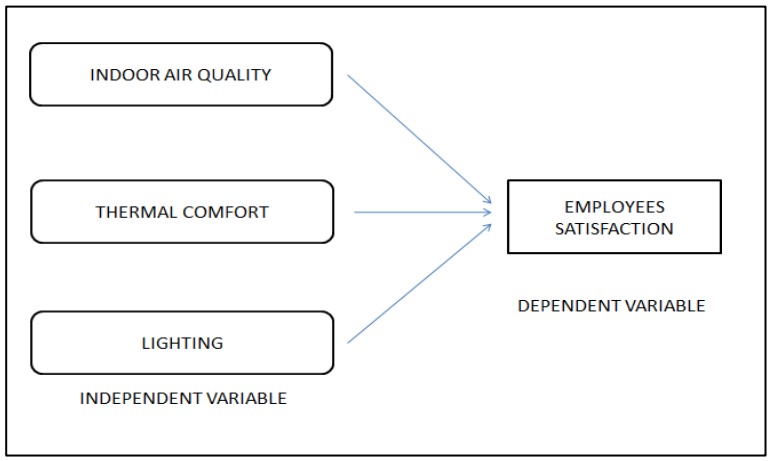

Figure 1: Conceptual Framework

3.0 METHODOLOGY

This study adopts a quantitative research approach to examine employee satisfaction with indoor environmental quality (IEQ), focusing on thermal comfort, indoor air quality, and lighting. Quantitative research allows for objective analysis using numerical data and statistical tools to identify patterns and relationships (Williams, 2007; Bryman, 2019). The research follows a positivist paradigm and a deductive strategy, using structured survey questionnaires as the primary data collection tool (Creswell, 2014). This method enables efficient and cost-effective data gathering from a large sample (Kurzhals, 2021). The questionnaire, administered online via Google Forms, includes four sections: demographic data, employee satisfaction with IEQ, evaluation of current workplace conditions, and suggestions for improvement. It uses Likert scales to measure perceptions and includes both closed and open-ended questions to collect comprehensive feedback. The respondent consists of 67 employees from BMES Maintenance Services Sdn. Bhd., working across three UiTM campuses: Seremban, Rembau, and Puncak Alam. Convenience sampling was used to select participants based on accessibility (Golzar et al., 2022). Data will be analyzed using SPSS software, employing descriptive statistics to identify trends, Cronbach's alpha to assess reliability, and factor analysis to explore underlying relationships among IEQ variables.

4.0 RESULTS AND DISCUSSION

Data collected from respondents at BMES Maintenance SDN BHD branches in UiTM Seremban, UiTM Puncak Alam, and UiTM Rembau were analyzed using SPSS software. Descriptive statistical methods such as means, percentages, and frequency distributions were employed to summarize and interpret employee satisfaction levels towards indoor environmental quality.

4.1 Analysis on Demographic Respondent

The demographic profile of the respondents includes their personal information and questions related to their behaviour. The behavioural questions are designed to assess the respondents ability to recall information (Bryman, 2012). This study also collected personal information such as age range, gender, length of service, and department of the respondents. Table 1 show the demographic profile respondent (N=67).

Table 1: Demographic Profile Respondent (N=67)

Demography		**Frequency**	**Percentage**
Gender	Male Female	50 17	74.6 25.4
Age group	Under 25 26 – 35 36 – 45 Above 46	26 34 6 1	38.8 50.7 9 1.5
Length of services	Less than 3 years 3 – 6 years 7 – 10 years More than 11 years	10 17 32 8	14.9 25.4 47.8 11.9
Position	Top Management Middle Management Operations Department	3 21 43	4.5 31.2 64.2
Location	UiTM Seremban UiTM Rembau UiTM Puncak Alam	26 19 22	38.8 28.4 32.8

Table 1 show the demographic profile of the 67 respondents in the study. The majority were male (74.6%) and primarily aged between 26–35 years (50.7%), indicating a predominantly young, male workforce. Most had 7–10 years of service (47.8%), suggesting a relatively experienced employee group. Operational staff made up the largest proportion (64.2%), followed by middle management (31.3%), with top management minimally represented (4.5%). Respondents were fairly distributed across the three UiTM campuses, with UiTM Seremban having the highest participation (38.8%), followed by Puncak Alam (32.8%) and Rembau (28.4%).

4.2 Analysis on Objective One

This section analyzes quantitative data to achieve the first research objective is to identifying factors influencing employees' satisfaction with indoor environment quality specifically indoor air quality, thermal comfort, and lighting in facility management organizations. Data was collected using questionnaires distributed to employees of BMES Maintenance Services SDN BHD across three sites: UiTM Seremban, UiTM Rembau, and UiTM Puncak Alam. The data was analyzed using SPSS, with mean analysis employed to determine the average scores for each item. This approach enabled the researcher to identify key factors affecting employee satisfaction within the context of indoor environmental conditions in facility management.

Table 2: Descriptive Statistic for Identify The Factor That Influences Employees Satisfaction Towards Indoor Environment Quality

INDOOR AIR QUALITY		
QUESTION	Mean	Ranking
1. Circulation of fresh air increases your satisfaction at the workplace.	3.78	4
2. An odor-free working environment makes your workspace more comfortable.	3.69	5
3. Appropriate air humidity levels increase your comfort while working.	3.82	3
4. A good air conditioning system at the workplace increases your satisfaction.	3.99	2
5. The effectiveness of the ventilation system positively affects your work experience	4.13	1
THERMAL COMFORT		
1. Uniform temperature throughout the workspace influences your satisfaction.	3.78	1
2. Ability to control temperature according to preference influences your comfort.	3.51	5
3. Normal workplace temperature makes your workspace more comfortable.	3.61	4
4. Effective air conditioning system influences your work experience.	3.64	3
5. Temperature adjustments according to weather changes influence your satisfaction.	3.72	2
LIGHTING		
1. Adequate brightness levels increase your satisfaction in the workplace.	3.51	3
2. Access to natural sunlight influences your mood while working.	3.33	5
3. Absence of disturbing glare increases your comfort in the workplace.	3.61	2
4. Ability to adjust lighting levels influences your satisfaction.	3.49	4
5. Uniform lighting throughout the workspace influences your work experience.	3.69	1

Table 2 shows the findings on the factors that influence employees satisfaction towards indoor environment quality within a facility management organization, focusing on three key dimensions: Indoor Air Quality, Thermal Comfort, and Lighting. Among these, Indoor Air Quality was found to have the strongest influence, with the effectiveness of the ventilation system ranked highest (mean = 4.13), indicating that proper air circulation and system performance significantly enhance employee satisfaction. In the Thermal Comfort category, maintaining a uniform temperature throughout the workspace had the greatest impact (mean = 3.78), showing that temperature consistency is more valued than individual control. Meanwhile, in the Lighting category, the absence of disturbing glare and uniform lighting were rated as the most influential factors (both with mean = 3.69), reflecting employees' preference for visually comfortable and consistent lighting conditions. On the other hand, access to natural sunlight received the lowest mean score (3.33), suggesting it may be less accessible or less impactful in this specific workplace setting. Overall, the results indicate that ventilation effectiveness, temperature uniformity, and glare control are the primary factors influencing employee satisfaction with indoor environmental quality in a facility management context.

4.3 Analysis on Objective Two

This section analyzes data to address the study second objective to analyze factors influencing employee satisfaction with indoor environmental quality specifically indoor air quality, thermal comfort, and lighting within BMES Maintenance Services Sdn. Bhd. Quantitative data collected via questionnaires from employees at UiTM Seremban, UiTM Rembau, and UiTM Puncak Alam were analyzed using SPSS, with mean analysis used to determine average satisfaction

levels. Table 3 presents the findings, offering valuable insights into how indoor environmental conditions impact employee satisfaction in facility management organizations.

Table 3: Descriptive Statistic for Analysis Factors That Influence Employees Satisfaction Towards Indoor Environment Quality

INDOOR AIR QUALITY		
QUESTION	Mean	Ranking
1. Air freshness in your workspace.	3.67	4
2. Effectiveness of unpleasant odor control.	3.52	5
3. Appropriateness of air humidity levels.	3.69	3
4. Performance of the air conditioning system.	3.84	2
5. Overall effectiveness of the ventilation system.	4.01	1
THERMAL COMFORT		
1. Temperature uniformity throughout the workspace.	3.69	1
2. Ease of temperature control.	3.49	4
3. Normal and comfortable workplace temperature.	3.4	5
4. Effectiveness of the air conditioning system.	3.55	3
5. Effectiveness of temperature adjustments according to weather.	3.58	2
LIGHTING		
1. Adequacy of brightness levels.	3.48	3
2. Access to natural sunlight in the workplace.	3.34	4
3. Effectiveness of glare control.	3.57	2
4. Options to adjust lighting.	3.48	3
5. Uniformity of lighting throughout the workspace.	3.75	1

Based on Table 3, the overall assessment of workplace environmental comfort reveals that Indoor Air Quality received the highest satisfaction, with mean scores ranging from 3.52 to 4.01. The most positively rated aspect was the effectiveness of the ventilation system (mean = 4.01), indicating strong air circulation performance, while lower scores for unpleasant odor control (mean = 3.52) and air freshness (mean = 3.67) suggest the need for improved air quality management. Thermal Comfort showed moderate satisfaction, with mean scores between 3.40 and 3.69; the uniformity of temperature was rated the highest (mean = 3.69), whereas the perception of a normal and comfortable temperature received the lowest score (mean = 3.40), highlighting issues in temperature regulation. For Lighting, mean scores ranged from 3.34 to 3.75, with uniform lighting receiving the highest rating (mean = 3.75) and access to natural sunlight the lowest (mean = 3.34), indicating limited daylight exposure. In summary, while mechanical systems such as ventilation and artificial lighting are generally effective, improvements in natural environmental aspects like odour control, temperature comfort, and access to daylight are essential to enhance overall employee satisfaction with the indoor environment.

4.4 Bar Graph

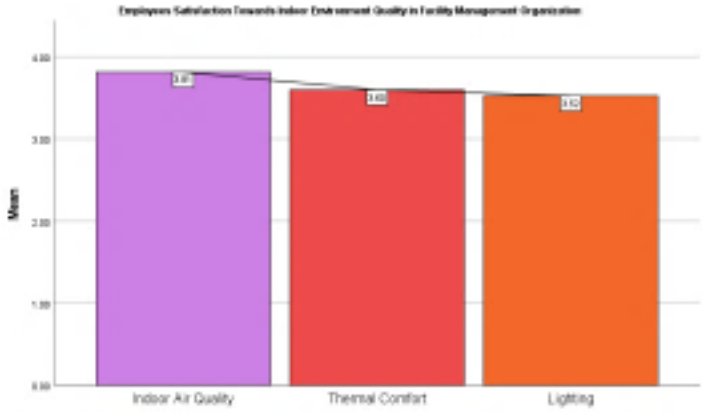

Figure 2: Bar Graph for Employees Satisfaction Towards Indoor Environment Quality

Figure 2 shows employee satisfaction towards Indoor Environment Quality (IEQ) in the facility management organization across three UiTM campuses. Indoor Air Quality (IAQ) recorded the highest mean score of 3.81, followed by Thermal Comfort at 3.60, and Lighting at 3.52. This indicates that employees are most satisfied with IAQ, suggesting good ventilation and air freshness across campuses. Thermal Comfort also shows a relatively high satisfaction level, though slightly lower, pointing to acceptable but improvable temperature conditions. Lighting scored the lowest, indicating potential issues with brightness, adjustability, or natural light availability. The analysis reveals important trends in employee satisfaction. High IAQ scores align with studies highlighting the importance of proper HVAC systems for health and productivity. Thermal Comfort, though satisfactory, may be influenced by factors like humidity and air movement. Lighting, while still above average, shows the greatest opportunity for improvement, especially in enhancing visual comfort and energy levels. These findings suggest that improving lighting conditions, while maintaining good air quality and thermal settings, can further enhance workplace satisfaction and performance.

4.5 Analysis on Objective Three

This section presents the findings for Objective Three, which aims to propose recommendations for improving indoor environmental quality (IEQ) to enhance employee satisfaction. Data was collected using open-ended questions in a Google Form, distributed to staff at BMES Maintenance Sdn. Bhd. across three sites: UiTM Seremban, UiTM Rembau, and UiTM Puncak Alam. The suggestions provided by respondents are compiled and presented in table format for clearer analysis and interpretation.

Table 4: Recommendation for Improving IEQ to Enhance Employee Satisfaction

Recommendations to Improve Indoor Environmental Quality to Enhance Employee Satisfaction.		
1 Workspace Layout Improvement	12	17.91%
2. Air Conditioning (HVAC)	11	16.42%
3. Lighting Improvement	8	11.94%

4. Cleanliness & Odor Control	6	8.96%
5. Ventilation System Enhancement	6	8.96%
6. Employee Well-being (Comfort Items)	5	7.46%
7. Technology Integration (Sensors)	3	4.48%
8. Smoking Control Measures	3	4.48%
9. Communication & Feedback	2	2.99%
10. Workshop/Utility Space	2	2.99%
11. Noise Reduction	1	1.49%
12. No Suggestion / Empty	8	11.94%

Table 4 shows the recommendations for improving Indoor Environmental Quality (IEQ) to enhance employee satisfaction. The findings reveal that the most frequently suggested improvements focus on workspace layout (17.91%), highlighting the importance of a more organized and conducive working environment. This is followed by calls for better air conditioning systems (16.42%) and enhancements in lighting conditions (11.94%), indicating the need for improved thermal comfort and visual comfort in the workplace. Other notable suggestions include more frequent cleaning, improved ventilation, the addition of ergonomic furniture, the introduction of indoor plants, and the implementation of smart systems such as automatic sensors for temperature and lighting control. Employees also emphasized the need to address indoor air quality by reducing indoor smoking and increasing awareness through health education. Overall, the data suggests that addressing these key areas can significantly contribute to a healthier, more comfortable, and productive work environment.

CONCLUSION

This study demonstrates that Indoor Environmental Quality (IEQ) significantly contributes to enhancing employee satisfaction in facility management organizations managed by BMES Maintenance Services Sdn Bhd. The analysis revealed that all three IEQ components such as indoor air quality, thermal comfort, and lighting are strongly supported by respondents and positively influence workplace satisfaction. Among these, indoor air quality was identified as the most impactful, followed closely by thermal comfort and lighting conditions. The findings emphasize the importance of effective ventilation systems, temperature uniformity, and adequate lighting in reducing employee discomfort and improving overall workplace experience. These insights provide practical implications for facility management strategies in educational settings, especially in addressing issues such as poor air circulation, temperature inconsistencies, and insufficient natural lighting. For future implementation, it is strongly recommended that organizations establish comprehensive employee feedback systems for continuous IEQ assessment and integrate advanced smart building technologies for automated environmental adjustments. Further research should endeavour to expand the scope by incorporating a larger and more diverse sample of respondents across various facility management organizations and industrial sectors to enhance the generalizability and robustness of the findings.

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Factors Affecting Outsourcing Decisions for Elevator Maintenance Management in Hospitals

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ABSTRACT

Outsourcing elevator maintenance in hospitals requires careful consideration of service quality, risk and liability, and technological expertise to ensure reliable operations and patient satisfaction. This study aims to propose best practices for outsourcing elevator maintenance management by identifying, analyzing, and addressing factors influencing such decisions Hospital elevator maintenance is crucial for patient care, but choosing between in-house and outsourced services poses challenges in technical expertise, response time, and compliance with safety standards. Outsourcing offers higher technical skills but carries risks of delays and miscommunication, while in-house teams often struggle with modern systems making it essential to balance service quality, risk, and operational efficiency. Using a qualitative approach, data were collected through interviews with 15 competent respondents and analyzed using thematic analysis. Thematic analysis was used to identify key themes and patterns emerging from the interview data. Findings revealed that service quality, risk and liability, and technological expertise are pivotal factors impacting outsourcing outcomes. The study concludes that hospitals must adopt tailored strategies to mitigate risks, enhance service quality, and leverage specialized expertise. By integrating these best practices, hospitals can achieve cost-effective and efficient elevator maintenance, ensuring compliance with safety standards and uninterrupted operations. This research contributes to the field by offering actionable insights for healthcare facilities to optimize outsourcing decisions and maintain high operational standards.

Keywords: Outsourcing, Elevator, Maintenance, Quality, Technological

1.0 INTRODUCTION

1.1 Research Background

The advancement of elevator technology in hospitals has increased the reliance on outsourcing maintenance services, especially due to the need for specialized skills and equipment, as highlighted by Lee et al. (2020). Although outsourcing offers benefits such as improved system reliability, compliance with safety standards, and reduced operational disruptions, it also brings concerns related to vendor reliability, quality of service, and risk management (Gomez & Perez, 2020). This research is essential for improving service delivery and ensuring patient safety in modern healthcare facilities.

1.2 Aim and Research Objectives

The aim of this study is to propose best practices for outsourcing elevator maintenance management in hospitals by examining the key factors that influence outsourcing decisions. In line with this aim, the research sets out several specific objectives to guide the investigation and effectively address the research question. First, the study seeks to identify the factors affecting outsourcing decisions for elevator maintenance in hospital settings, focusing on areas such as service quality, risk and liability, and technological expertise. Second, the study aims to analyze these identified factors to understand their impact and interrelation in the context of hospital facility management. Lastly, the research intends to recommend effective strategies for improving decision-making processes related to outsourcing elevator maintenance management. These

strategies will be formulated based on a comprehensive evaluation of the influencing factors, with the goal of ensuring optimal service quality, enhancing risk mitigation, and promoting the adoption of advanced technology within hospital environments.

2.0 LITERATURE REVIEW

This chapter presents findings from relevant journals and scholarly articles, addressing key issues related to elevator maintenance outsourcing in hospitals. Elevator systems are critical for hospital operations, supporting patient movement, emergency response, and staff efficiency. Outsourcing these services offers benefits such as access to specialized expertise, advanced technology, and cost savings, but also raises challenges like service quality concerns, liability risks, and reduced internal control (Anderson et al., 2021). In-house teams provide greater oversight but often lack the technical capabilities needed for modern systems. The most effective approach depends on balancing cost, safety, and long-term operational value (Wilson et al., 2022).

2.1 Outsourcing

Outsourcing, the practice of delegating internal tasks to external providers, has become common across industries for cost savings and access to specialized expertise (Ka Leung LOK, 2013). It allows organizations to focus on core competencies while enhancing efficiency (Boguslauskas & Kvedaraviciene, 2009). However, outsourcing can lead to higher hidden costs, reduced customer interaction, and compromised service quality (Johnson et al., 2013). Miscommunication with providers unfamiliar with the organization's values may also harm reputation and customer satisfaction (Relph & Parker, 2014). Therefore, outsourcing requires careful planning and oversight.

2.2 Outsourcing in Hospital

Outsourcing elevator maintenance allows hospitals to focus on patient care while ensuring safe and efficient operations through specialized providers. As systems grow more complex, outsourcing offers access to advanced technologies and expert maintenance, reducing downtime and ensuring compliance with safety standards (Johnson et al., 2020). Service quality is critical, with hospitals using performance-based contracts and regular reviews to ensure reliability (Voss et al., 2020). Risk management and compliance are addressed through clear contracts and regular audits (Anderson et al., 2021). Strategic vendor partnerships also help hospitals adapt to future technological advancements.

2.3 Elevator Maintenance Management

Elevator maintenance is crucial for ensuring safety and reliability, particularly in high demand environments like hospitals. Preventive and predictive maintenance strategies, such as IoT sensors and predictive analytics, help identify issues early and reduce downtime (Wilson et al., 2022). Outsourcing elevator maintenance provides access to specialized expertise and advanced tools, but requires careful vendor selection and performance-based contracts to maintain quality (Smith, 2020). Technological advancements like AI-driven diagnostics improve efficiency, though challenges such as high costs and labour shortages remain (Harris & Liu, 2021). Organizations that embrace these innovations can improve system reliability and long-term operational efficiency.

2.4 Service Quality

Service quality is crucial in hospital elevator maintenance due to safety and operational demands. Outsourcing to specialized providers often ensures higher reliability through advanced technology

and trained staff (Voss et al., 2020). Performance-based contracts and regular evaluations help maintain standards (Smith & Brown, 2019). However, hospitals must carefully select vendors to avoid service lapses and balance cost with quality.

2.5 Risk and Liability

Outsourcing shifts responsibility to vendors, requiring clear contracts to manage liability and ensure compliance (Anderson et al., 2021). Hospitals mitigate risks with audits, vendor assessments, and legal safeguards like insurance and indemnity clauses (Davis, 2018).

2.6 Technological and Expertise Requirements

Modern elevator systems require expertise hospitals may lack. Outsourcing gives access to tools like IoT and predictive analytics (Wilson et al., 2022). Partnering with tech-savvy providers ensures efficiency, though effective coordination is essential (White & Johnson, 2018).

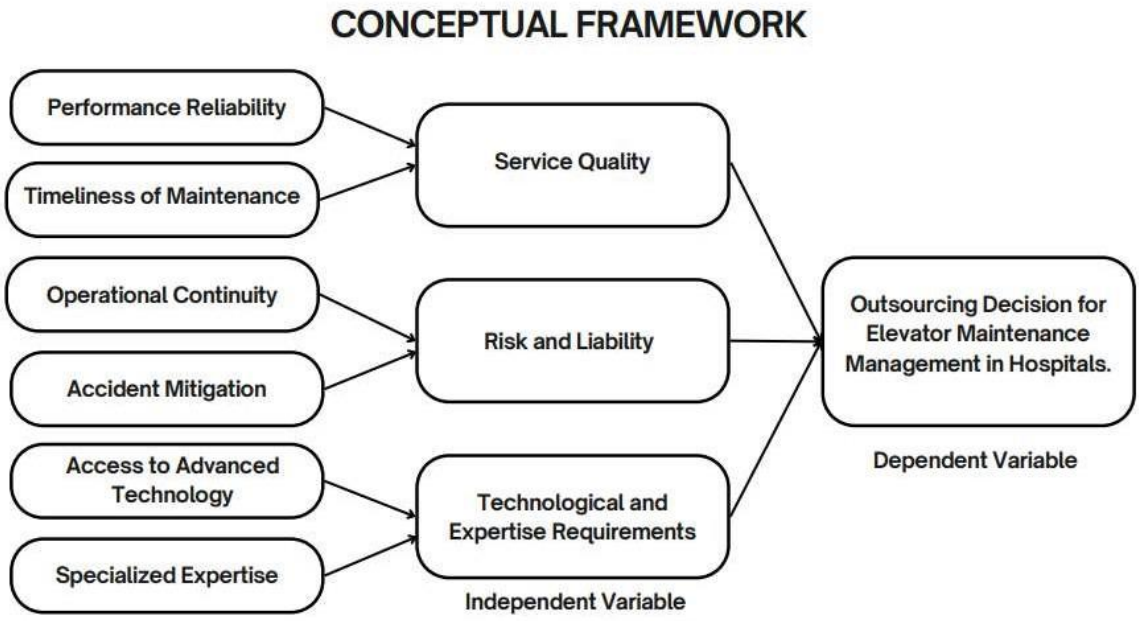

Figure 1 : Conceptual Framework

Figure 1 above presents a conceptual framework for the factors influencing outsourcing decisions for elevator maintenance management in hospitals. The framework highlights three key variables: Service Quality, Risk and Liability, and Technological and Expertise Requirements. These elements play a critical role in shaping how hospitals choose and manage outsourced service providers. By analyzing their impact, the study aims to identify best practices that can guide hospitals in making informed outsourcing decisions. The framework supports the goal of improving elevator maintenance outcomes while ensuring safety, operational efficiency, and long-term value through strategic outsourcing.

3.0 METHODOLOGY

This study, following the Research Onion framework (Saunders et al., 2019), is grounded in an interpretivist philosophy, which emphasizes understanding the subjective experiences of individuals involved in hospital facility management, particularly in outsourcing decisions for elevator maintenance (Bell, Bryman, & Harley, 2022). An inductive approach supports theory development from empirical data, ideal for under-researched contexts (Creswell & Poth, 2018).

The research adopts a qualitative methodology using a case study design, allowing an in-depth investigation of hospitals that outsource elevator services (Yin, 2018). Semi-structured interviews serve as the primary strategy to explore participants' perspectives (Kallio et al., 2016). A cross-sectional time horizon captures current decision-making factors at a single point in time, offering practical insights into present practices (Saunders et al., 2019).

3.1 Population and Sampling

The study focuses on three public hospitals in Negeri Sembilan and targets participants directly involved in elevator maintenance outsourcing. Using purposeful sampling, the research includes key stakeholders such as facilities managers, procurement officers, hospital engineers, and technical supervisors. This method ensures that the data collected is rich, specific, and contextually relevant, capturing insights from both strategic decision-makers and operational staff (Palinkas et al., 2019). By involving 15 experts with first-hand experience in managing elevator maintenance in hospital settings, the study enhances the reliability and depth of its findings, offering a comprehensive understanding of the factors influencing outsourcing decisions in healthcare facility management.

3.2 Research Instrument

For this research paper, the questionnaire design follows an interview protocol and adopts a semi-structured method with open-ended questions to facilitate in-depth exploration. The questionnaire is divided into two main sections: Part A and Part B, each carefully organized to ensure clarity and alignment with the research objectives. Part A addresses the first and second research objectives by identifying factors that influence outsourcing decisions for elevator maintenance in hospitals, comprising 13 open-ended questions structured around three key variables: service quality, risk and liability, and technological and expertise requirements. Part B corresponds to the third objective, presenting three questions one per variable focused on gathering expert suggestions to enhance decision-making strategies in elevator maintenance outsourcing. This semi-structured, sentence-format approach offers flexibility for participants to elaborate on their experiences while maintaining consistency in data collection (Marshall & Rossman, 2016). By allowing participants to articulate their insights freely, this method fosters engagement and uncovers nuanced perspectives, ultimately enriching the depth and validity of the findings (Denzin & Lincoln, 2018).

3.3 Data Analysis, Reliability and Validity

For this research paper, thematic analysis is used to identify and report patterns within qualitative data, making it ideal for exploring the factors influencing outsourcing decisions for elevator maintenance management in hospitals. This approach provides a nuanced understanding of complex issues. The validation process ensures data accuracy and trustworthiness through expert feedback, comparison with existing studies, and consistency checks. Key concepts in validation include validity, which ensures the questionnaire measures what it intends to, and reliability, which guarantees consistency over time. Although no pilot test was conducted, the qualitative, semi-structured approach ensures the questionnaire effectively captures relevant insights, maintaining flexibility and adaptability in the research design

4.0 RESULTS AND DISCUSSION

The research paper has 13 questions divided into two sections: variables and suggestions for improvement. Section A has three variables: service quality, risk and liability, and technological and expertise requirements. Each variable contains three questions. In section B, the question focuses to enhance decision-making strategies in elevator maintenance outsourcing. This chapter

will also give the results of the study from the data collection that has been done. According to Creswell, (2019), a range of 5-25 respondents are acceptable for qualitative study. By including 15 participants, such as Facility Manager (FM) and Executive Operations (EO), the study leverages their first-hand experience to ensure the reliability and robustness of the data collected.

4.1 Profile of interviewees

Table 1: Profile of Respondents

Interviewee	Occupation	Experience **(years)**
P1	Facility Manager (FM)	20
P2	Head of FEMS (Facility Engineering Maintenance Services)	20
P3	Executive Operations (EO) Chargeman A4	22
P4	Executive Operation (EO) Chargeman BO	25
P5	Vendor Elevator Operations	20
P6	Facility Manager (FM)	20
P7	Head of FEMS (Facility Engineering Maintenance Services)	20
P8	Executive Operations (EO)	23
P9	Senior Technical Operation (STO)	20
P10	Vendor Elevator Operations	21
P11	Facility Manager (FM)	20
P12	Head of FEMS (Facility Engineering Maintenance Services)	20
P13	Executive Operations (EO)	25
P14	Senior Technical Operation (STO)	20
P15	Vendor Elevator Operations	20

4.2 Analysis on the Factors Affecting Outsourcing Decisions for Elevator Maintenance Management in Hospitals

4.2.1 Variable 1: Service Quality

For the first question (A1.1) that was asked to interviewees about the specific aspects of service quality influencing hospital management's decision to outsource elevator maintenance, participants emphasized the importance of fast response times, service reliability, and the ability to handle emergencies effectively. For the second question (A1.2) regarding how hospitals assess the performance of outsourced maintenance service providers, participants referred to the use of KPIs, regular audit reports, and feedback from hospital staff as key tools for evaluation. For the third question (A1.3) on how response times impact the perception of service quality in outsourced maintenance, participants highlighted that quicker response times lead to greater trust and satisfaction in the service provider's professionalism and capability. Overall, participants highlighted that strong service quality demonstrated by immediate responds, regular monitoring, and reliable performance is a significant element in outsourcing decisions. In Table 2, these three themes reflect the core insights from the interview responses, capturing the quality expectations and assessment strategies in hospital elevator maintenance outsourcing.

Table 2: Themes and Quotations from Interview Responses on Service Quality

No Cod	Theme	Quotations
A1.1	**Fast response time and reliability**	"We need fast and reliable service, especially during emergencies."
A1.2	**KPI evaluation and audit reports**	"We monitor their performance using KPIs, audit reports, and user feedback from staff."
A1.3	**Faster response equals higher trust and satisfaction**	"The faster they respond, the more we trust their professionalism and capability."

4.2.2 Variable 2: Risk and Liability

For the first question (A2.1) that was asked to interviewees about the impact of outsourcing on hospital liability in the event of elevator malfunctions, participants agreed that outsourcing helps reduce direct liability, as legal and operational responsibility is transferred to the service provider. For the second question (A2.2) regarding how contract management influences risk and liability, participants emphasized the importance of having clearly defined contracts that outline roles, responsibilities, and expectations to minimize potential disputes and manage risk effectively. For the third question (A2.3) on how hospitals can mitigate risks when outsourcing elevator maintenance services, participants highlighted the need to select qualified and certified contractors and to conduct continuous monitoring to ensure compliance and safety. Overall, participants highlighted that effective risk and liability management in outsourcing requires well-structured contracts, cautious contractor selection, and proactive oversight. In Table 3, these three themes represent the core strategies and precautions adopted by hospitals to safeguard their interests when outsourcing elevator maintenance.

Table 3: Themes and Quotations from Interview Responses on Risk and Liability

No Cod	Theme	Quotations
A2.1	**Reduced direct liability for hospitals**	"Outsourcing helps reduce our direct liability because the responsibility falls on the service provider."
A2.2	**Clearly defined contracts reduce risk**	"With a well-defined contract, we can assign clear responsibilities and reduce potential risks."
A2.3	**Select qualified contractors and monitor performance**	"We select qualified, certified contractors and continuously monitor their work to manage risks."

4.2.3 Variable 3: Technological and Expertise Requirements

For the first question (A3.1) that was asked to interviewees about the expertise an outsourced elevator maintenance provider should possess, participants agreed that providers must have certified and experienced technicians who are familiar with hospital-specific elevator systems and safety requirements. For the second question (A3.2) regarding how hospitals assess the technological capabilities of outsourced providers, participants highlighted the use of site visits, technical evaluations, and reviews of past project performance as key methods for verification. For the third question (A3.3) on how a lack of skilled labor in elevator technology

affects outsourcing decisions, participants noted that the absence of in-house expertise is a major driver behind outsourcing, pushing hospitals to seek contractors with proven technical competence. Overall, participants emphasized that technological expertise, verified through certifications and practical assessments, plays a critical role in outsourcing decisions for elevator maintenance in hospitals. In Table 4, these three themes reflect the core considerations that guide hospitals in selecting qualified and capable maintenance providers.

Table 4: Themes and Quotations from Interview Responses on Technological and Expertise Requirements

No Cod	Theme	Quotations
A3.1	**Certified and experienced technicians**	"They must have certified and experienced technicians who understand hospital-specific elevator systems."
A3.2	**Site visits and technical evaluations**	"We conduct site visits and review technical documents and previous project performance."
A3.3	**Drives the need to outsource**	"We outsource because of limited internal expertise, so we look for certified and experienced technicians, assess their capabilities through site visits and technical reviews to ensure they meet hospital standards."

4.3 Analysis on the Factors Affecting Outsourcing Decisions for Elevator Maintenance Management in Hospitals

For the suggestion regarding quality standards (B1.1), interviewees shared additional strategies to optimize service quality in elevator maintenance contracts. P1 proposed the inclusion of detailed service level agreements (SLAs), while P2 recommended scheduled quality audits. P3 emphasized routine inspections and documentation, P4 advocated for penalties tied to poor performance, and P5 highlighted the importance of real-time monitoring tools to ensure service reliability. These perspectives collectively underscore a proactive and structured approach to enhancing service quality through contractual and operational controls.

In discussing risk management strategies (B2.1) for outsourcing elevator maintenance, participants shared several practical measures. P6 stressed the need for risk-sharing clauses within contracts, P7 recommended regular legal and compliance reviews, and P8 suggested the integration of emergency response protocols. P9 advocated for contractor insurance verification, and P10 proposed scenario-based risk drills to prepare for system failures. These insights highlight the necessity of a comprehensive risk management plan that is embedded in both legal frameworks and operational procedures.

Lastly, to ensure the employment of certified and experienced technicians (B3.1), participants offered actionable improvement measures. P11 emphasized mandatory certification checks during procurement, P12 proposed collaboration with technical institutions for talent pipelines, P13 recommended performance-based renewal criteria, P14 suggested third-party technical assessments, and P15 supported continuous up skilling programs conducted by the vendors themselves. These measures demonstrate a commitment to maintaining technical competence and service excellence through consistent evaluation and development efforts.

In Table 5, these three themes represent the key recommendations from the interview responses, outlining targeted strategies to enhance service quality, mitigate risk, and uphold technical standards in outsourced elevator maintenance within healthcare facilities.

Table 5: Themes and Quotations for Enhancing the Effectiveness of decision-making strategies in elevator maintenance outsourcing

No Cod	Theme	Quotations
B1.1	**Include clear SLAs and digital monitoring**	"Include clear Service Level Agreements (SLAs) and use digital monitoring tools to maintain consistent quality in service."
B2.1	**Regular audits and insurance requirements**	"Conduct regular audits and ensure that providers have proper liability insurance to reduce potential risks."
B3.1	**Mandatory certification and on-going training**	"Make it mandatory for providers to hire certified technicians and ensure they undergo continuous training as part of the contract."

5.0 CONCLUSION

The study examined the factors influencing outsourcing decisions for elevator maintenance management in hospitals. The study concludes that outsourcing decisions for elevator maintenance in hospitals are significantly influenced by three key factors: service quality, risk and liability, and technological and expertise requirements. High service quality is essential, with hospitals emphasizing the need for fast response times, reliable performance, and clear Service Level Agreements (SLAs) supported by digital monitoring and performance indicators. In terms of risk and liability, outsourcing can reduce hospital exposure by transferring responsibilities to external providers, but this requires strong contract management, regular audits, and insurance verification to safeguard institutional interests. The lack of in-house technical expertise is another major driver, leading hospitals to depend on certified and experienced outsourced technicians. Ensuring these qualifications involves mandatory certification, ongoing training, and periodic technical evaluations. While outsourcing offers benefits like cost efficiency and improved operational reliability, challenges such as over-dependence on vendors and inconsistent service must be managed through strategic planning and continuous oversight. By addressing these three factors effectively, hospitals can optimize outsourcing decisions, maintain safety and compliance standards, and ensure uninterrupted elevator operations. This study provides actionable insights for healthcare facility managers seeking to enhance elevator maintenance outcomes through well-informed, structured outsourcing practices.

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Impact of Communication Towards Employee Performance at Facilities Management (Healthcare Building)

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ABSTRACT
Many companies often overlook the importance of effective communication, despite its significant influence on employee performance. This research aimed to propose strategies for improving communication effectiveness to enhance employee performance within a facility management company. A qualitative research approach was employed, using semi-structured interviews as the primary data collection method. The study was conducted at three Medivest-operated hospitals in Negeri Sembilan: Hospital Tuanku Ja'afar (Seremban), Hospital Tampin, and Hospital Port Dickson. A total of nine participants, comprising facility managers, technicians, and maintenance supervisors, were interviewed. The use of semi-structured interviews enabled participants to share their insights and experiences in a conversational and open-ended format. The collected qualitative data were analyzed through content analysis to identify recurring patterns and themes. These findings are expected to offer a deeper understanding of the communication factors that affect employee performance within the context of facilities management. The results of this research can help inform policy development, communication strategies, and training programs to improve productivity through better communication practices.

Keywords: communication, employee, performance, facilities, management,

1.0 INTRODUCTION

1.1 Research Background
Effective communication is crucial for employee engagement, productivity, and success in organizations, especially in facilities management teams. Research has shown that open communication leads to increased job satisfaction and productivity, while poor communication reduces morale and performance. However, there is a lack of research specifically examining communication and performance in healthcare settings. This research aims to develop an interview methodology to study how communication influences employee performance among facilities management staff in healthcare facilities. The study has potential benefits for broader organizational communication theories, healthcare operations, workforce development strategies, and efficiency improvement through data-driven communication improvements. The research aims to fill the research gap and provide practical and theoretical value. In modern business environments, which are marked by increased levels of competition, companies are driven to improve the performance of their employees in order to fulfil the goals and objectives that they have set for themselves. Employee performance is affected by the communication that takes place in the workplace as well as the physical environment themselves. According to Setyawati et al. (2022), improvements in employee performance can be attributed to a number of factors, including the availability of good communication and a positive work environment. There is a considerable allocation of working days, equal to 385 million, by employees in the eastern region of the United States, allocated to addressing workplace concerns, particularly those linked to leadership communication, according to Dunford (2020). This allocation of working days is significant. According to Trojak (2020), a considerable majority of employees,

ranging from 65% to 75%, attribute their failures to lower-level management. This is based on empirical facts that have been gathered. There is a growing recognition of the value of internal communication in the context of efficiently managing and developing employee engagement inside businesses (Meirinhos et al., 2022). The necessity of informing, involving, and inspiring employees through effective internal communication practises is increased for businesses as a result of the growing competition and the must to adapt to new circumstances.

1.2 Aim and Objectives

The aim of the research is to propose strategy in enhancing the effectiveness of communication towards employee performance at facility management company.

This research aims to achieve the following objectives:

a To identify the communication factors that influence the employee performance at facility management company.

b To analyze the communication factors that influence the employee performance at facility management company.

c To suggest for enhancing the effectiveness of communication towards employee performance at facility management company.

2.0 LITERATURE REVIEW

The literature review highlights the significant impact of effective communication on employee performance. Various studies have established that strong communication skills lead to improved productivity, higher engagement, increased motivation, and greater job satisfaction among individuals and teams. Effective communication fosters a positive working environment, enhances collaboration, and helps in resolving conflicts, ultimately contributing to overall organizational success.

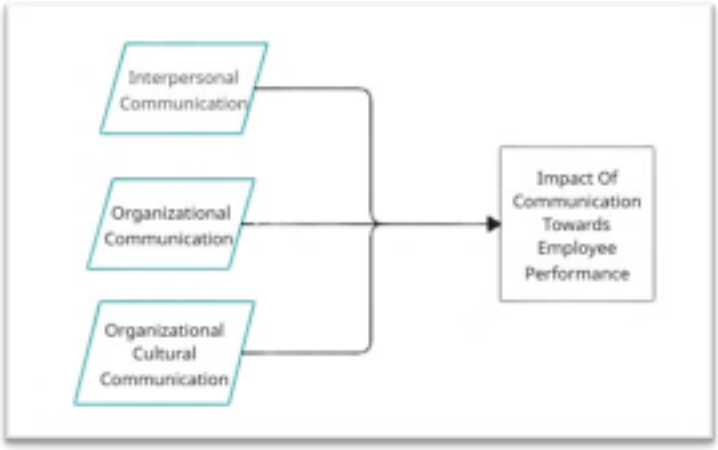

Figure 1 : Conceptual Framework

2.1 Impact of communication on employee performance

Performance outcomes are the outcomes of an employee's work done to achieve organizational objectives. It encompasses the extent to which employees fulfill their tasks and responsibilities in the workplace. Factors influencing employee performance include their understanding of the work, their level of excellence in their roles, and their knowledge and skills. Quality assessment

is determined by the employee's comprehension of the work and their level of expertise in their tasks. Quantity, on the other hand, measures output by the number of units produced or the frequency of completed activity cycles. This allows for the assessment of employee performance based on numerical counts of units or processes.

2.2 Interpersonal communication

Interpersonal communication involves the exchange of information, emotions, and interpretations through verbal and non-verbal means, particularly in face-to-face interactions. It includes the content and language of a message, as well as the manner in which it is conveyed, including non-verbal cues like tone of voice and body language. The linear model of communication, popular in diagrammatic representations, suggests a linear and unidirectional form of communication, but it may also occur without face-to-face interaction through various media.

2.3 Organizational communication

Organisational communication is the exchange of information within an organization to establish shared understanding and foster equality. It involves interpersonal interactions within individuals, small groups, and larger groups. Effective communication is crucial for employees to work harmoniously with one another and external entities. The environment of organisational communication influences members' experiences, behaviours, relationships, operations, growth, objectives, and adaptability. Establishing robust and interconnected channels of communication between employees and superiors can contribute to job satisfaction and promote a cohesive organizational environment. Ownership is important as it can generate genuine dedication among employees. Job dissatisfaction can result from inadequate communication due to personal issues, inter-unit competition, and lack of receptiveness from superiors.

2.4 Organizational cultural relationship

Organizational culture plays a crucial role in enhancing employee motivation for optimal performance. Strong organizational culture, both internally and externally, establishes a correlation between excellent performance and organizational culture. Employee performance is likely to improve when their individual performance is strong. Organizational culture is a shared attribute among all members, ensuring alignment with the organization's values, beliefs, and behavioral norms. Recognizing employee performance is important, as a decline in performance can impact the overall functioning of the entity. Organizational Communication Climate is a combination of perceptions of communication events, human behaviour, expectations, conflicts between personas, and opportunities for growth. O'Connor et al. (2008) identified four dimensions of organizational climate: responsibility, standards, rewards, and closeness and support.

3.0 METHODOLOGY

3.1 Participants of the research

The participants of this research consist of nine (9) executive levels, each selected from three different hospitals under the management of Medivest Sdn. Bhd., namely Hospital Tuanku Ja'afar, Hospital Tampin, and Hospital Port Dickson. A qualitative approach was used in conducting the interview process. The initial phase involved an in-depth review of relevant literature on topics such as organizational communication, staff performance, facilities management, and other related areas. Based on this review, a set of open-ended questions was developed to explore key themes and concepts identified in previous studies.

3.2 Instrument of the research

The interview technique was designed to ensure a coherent progression, beginning with introduction questions to establish rapport and acquire contextual information, and then proceeding to more in-depth questions to investigate the core research themes. The technique moreover incorporated prompts and subsequent inquiries to stimulate participants to expand upon their answers and furnish precise instances or encounters.

The completed interview methodology underwent validation by a panel of qualitative research professionals. They assessed to best standards, ability to collect comprehensive data, and overall appropriateness for addressing the research inquiries. The interview protocol was developed for implementation through semi-structured, individual interviews, providing flexibility and adaptability in accordance with the participant's answers, while maintaining consistency in the fundamental areas of investigation. The interviews have been captured using audio technology and then transcribed word-for-word for further qualitative analysis.

3.3 Data procedures

Subsequently, a validation phase was carried out with an accredited individual to assess the effectiveness of the interview protocol and identify any possible deficiencies or areas that may be enhanced. The interviews were transcribed and analysed to evaluate the calibre and comprehensiveness of the collected responses. These findings led to further improvements in the protocol, specifically in the areas of question language, sequence, and probing strategies. The interview technique was designed to ensure a coherent progression, beginning with introduction questions to establish rapport and acquire contextual information, and then proceeding to more in-depth questions to investigate the core research themes. The technique moreover incorporated prompts and subsequent inquiries to stimulate participants to expand upon their answers and furnish precise instances or encounters.

4.0 RESULTS AND DISCUSSION

The findings of this research revealed three prominent independent variables influencing workplace communication: **interpersonal communication**, **organizational communication**, and **culture communication**.

4.1 Variable 1 - Interpersonal Communication

Interpersonal communication emerged as a vital component across all participants' responses. Most participants emphasized the significance of face-to-face interactions, particularly in operational contexts such as briefings, troubleshooting, and coordination during audits. These direct interactions helped foster mutual understanding, facilitate quicker decision-making, and enhance problem-solving. For instance, structured team discussions, daily briefings, and one-on-one engagements were reported to aid in the efficient allocation of tasks and rapid response to urgent matters. However, breakdowns in interpersonal communication, such as misunderstandings or lack of feedback, often resulted in duplicated tasks, workflow disruptions, and strained relationships within teams. Several participants recounted scenarios where a misheard instruction or unclear verbal message led to delays, rework, or even safety risks. Suggestions for improvement frequently pointed toward adopting structured routines such as daily huddles, better documentation of meetings, and leveraging informal chats or messaging apps to maintain clarity and alignment.

4.2 Variable 2 - Organizational Communication

In terms of **organizational communication**, the use of formal channels like emails, memos, and meetings was acknowledged as foundational, though often supplemented by verbal or informal methods to ensure message clarity. Participants noted that while written communication is essential for record-keeping and official updates, it is not always effectively consumed or understood by all employees. Instances of ineffective organizational communication included poorly communicated policy changes, delayed SOP updates, and top down decisions lacking context, all of which negatively impacted operational readiness and employee engagement. This highlighted a recurring gap in upward and horizontal communication within organizations. To address these issues, participants recommended more proactive and transparent communication from management, timely updates on procedural changes, and fostering two-way dialogues, particularly during meetings and audits.

4.3 Variable 3 - Organizational Culture

Culture communication was deeply embedded in the workplace ethos, influencing how team members interacted and supported each other. The research found that mutual respect, shared values, and informal norms such as avoiding public criticism, recognizing unspoken distress signals, and encouraging safety reporting formed a foundation for psychological safety and motivation. Teams that practiced open, respectful communication and showed appreciation for contributions reported higher morale and stronger commitment to organizational goals. Conversely, overly critical or reactive communication environments were linked to disengagement and reduced trust. To reinforce positive culture communication, respondents suggested initiatives such as peer recognition programs, suggestion boards with rewards, monthly town halls, and informal feedback channels like tea-talks or breakroom discussions. These approaches were seen as effective in fostering an inclusive, communicative, and motivated workforce.

4.4 Suggestions And Recommendations

1. Interpersonal Communication

To enhance interpersonal communication, organizations should establish consistent routines such as daily check-ins, morning briefings, or end-of-day recaps. These short but regular interactions can help align teams, clarify responsibilities, and reduce task repetition. Furthermore, implementing “buddy systems” for new hires can ease the onboarding process and promote early relationship-building within teams. It is also recommended to improve the use of communication tools such as messaging apps or centralized dashboards to ensure that task updates and real-time information are shared openly and efficiently among team members. Additionally, encouraging more face-to-face interactions rather than relying solely on memos can build trust, improve understanding, and reduce miscommunication, especially in high-pressure or safety-sensitive situations.

2. Organizational Communication

To improve organizational communication, management should adopt a more proactive and transparent approach. Regular updates especially regarding procedural changes, policy updates, or organizational restructuring should be clearly communicated to all relevant departments. Management should also create structured opportunities for two-way communication, such as Q&A sessions during town halls or feedback loops after major decisions. Verbal reinforcement of important email content during meetings or toolbox sessions can ensure that critical information is fully received and understood. In addition, using a layered communication approach

(formal emails, informal chats, and decision focused meetings) can help accommodate different needs and urgency levels within the organization.

3. Culture Communication

A positive communication culture should be intentionally cultivated by reinforcing mutual respect, recognition, and openness. Leaders should model respectful dialogue, acknowledge team input, and avoid public criticism to maintain team harmony. Initiatives like peer recognition boards, monthly employee briefings, or "Employee of the Month" awards can promote morale and engagement. The use of suggestion boxes digital or physical should be encouraged, especially if paired with small rewards or visible follow-up, to empower employees to contribute ideas freely. Informal engagement methods, such as casual supervisor check-ins or tea-talk sessions, can also be instrumental in fostering trust and encouraging honest, two-way communication in a more relaxed environment.

In summary, organizations aiming to strengthen internal communication should focus not only on improving tools and structures but also on cultivating a respectful and inclusive communication culture. By addressing interpersonal, organizational, and cultural aspects together, the organization can achieve more cohesive teamwork, increased motivation, and improved overall performance.

4.5 Summary Findings and Analysis

Participant	Interpersonal Communication	Organizational Communication	Culture Communication
1.	**Types:** Strong face-to-face, daily morning briefings. **Impact:** One-on-one helps problem-solve; miscommunication causes delays (e.g., HVAC). **Suggestions:** Use group chats effectively to prevent repeated tasks.	**Types:** Emails/memos helpful but not fully read; prefer verbal reminders. **Impact:** Vague management communication (vendor switching) delayed procurement. **Suggestions:** Management be more proactive in sharing plans and regular updates.	**Types:** Respectful culture, open to raising issues. **Impact:** Daily updates/shout-outs boost morale. Silence in meetings signals issues, prompting follow-up. **Suggestions:** Visible suggestion board in workshop with rewards.
2.	**Types:** Face-to-face for planning/reporting; technical terms sometimes misunderstood by new staff. **Impact:** Teamwork crucial for asset planning; poor listening slows progress. **Suggestions:** Brief daily 5-min huddles for alignment.	**Types:** Emails for asset updates, meetings for clarification. **Impact:** Missed audit dat change from management caused scramble, affected performance. **Suggestions:** Management should take feedback seriously.	**Types:** Professional, constructive tone in meetings. **Impact:** Positive communication boosts ownership; top-down leads to disengagement. "Don't-blame" culture for equipment failures. **Suggestions:** Monthly town hall sessions for updates/concerns.

3.	**Types:** Critical face-to-face for safety issues; staff more receptive in person. **Impact:** Clear comms "save lives" by encouraging open dialogue; unclear feedback creates safety gaps. **Suggestions:** Better documentation of meeting discussions.	**Types:** Standardized memos for QHSE, followed by briefings. **Impact:** Confusing new inspection checklist (uncommunicated) wasted a week in redoing work. **Suggestions:** Clearer communication of expectations during audits/compliance checks.	**Types:** Mutual respect; everyone heard for safety. **Impact:** Open dialogue/feedback are norms, keeping staff alert. Silence from leaders creates uncertainty. Unspoken rule: immediately raise safety concerns. **Suggestions:** Recognition programs (emails/tokens) for speaking up.
4.	**Types:** Face-to-face practical, productive for daily coordination. **Impact:** Team discussions enhance learning; misunderstandings (misread fault code) disrupt workflow. **Suggestions:** Routine end-of day recaps for reflection.	**Types:** WhatsApp for technical alerts, emails for official docs. **Impact:** Last-minute site shutdown notification caused wasted preparation. **Suggestions:** More transparency from management on decisions impacting daily work.	**Types:** Mutual respect, especially among technical team. **Impact:** Casual supervisor check-ins boost motivation. Unspoken rule: avoid public criticism. **Suggestions:** Digital, anonymous suggestion box for honest feedback.
5.	**Types:** Face-to-face good for task monitoring, builds trust; junior staff need encouragement. **Impact:** Good comms coordinates shifts; unclear instructions cause confusion; misunderstandings lead to tension. **Suggestions:** More face-to face over memos.	**Types:** Emails/minutes clear, but points repeated verbally (staff don't check inboxes). **Impact:** Poor updates from management caused vendor contract renewal delay (lack of tools). **Suggestions:** Timely updates on SOP changes for adaptability.	**Types:** Workplace is learning environment; mistakes corrected constructively. **Impact:** Positive tone crucial; reactive/critical comms diminish commitment. Unwritten rule: solve issues together, debrief privately. **Suggestions:** Monthly briefings on achievements/ challenges

6.	**Types:** Structured weekly briefings with team leaders. **Impact:** Effective comms facilitate leadership; missteps due to misunderstandings delay projects. **Suggestions:** Create buddy systems for new hires for smoother info flow.	**Types:** Layered approach: emails (formal), meetings (decision), chat apps (quick). **Impact:** Vague reorganization plan caused confusion about reporting lines, took weeks to regain clarity. **Suggestions:** Encourage two-way communication; time for staff feedback in town halls.	**Types:** Leaders emphasize teamwork/respect. **Impact:** Transparency maintains motivation. Seniority plays a role (new staff listen more). **Suggestions:** Peer recognition wall in break room for morale and open comms.
7.	**Types:** Face-to-face effective during walkthroughs/audits. **Impact:** Direct consultation helpful; working in isolation ineffective. Misunderstanding readings adds unnecessary steps. **Suggestions:** Standardize reporting templates.	**Types:** Tracked via reports/Excel, discussed bi-weekly. **Impact:** Top management changing energy targets without context led to frustration, redoing plans. **Suggestions:** Managers visit floor more often for casual check-ins.	**Types:** Shared responsibility for energy savings, value input. **Impact:** Open comms fosters safety in ideas, encourages innovation. Unspoken norm: don't interrupt seniors unless emergency. **Suggestions:** Energy awareness campaigns with staff suggestions for two-way comms.
8.	**Types:** Heavily relies on face to-face during troubleshooting. **Impact:** Good comms allows quick responses; miscommunication leads to backlogs (duplicate orders). **Suggestions:** One daily short check-in meeting for proactive culture.	**Types:** Room for improvement; updates sometimes late via email, prefer verbal. **Impact:** Left out of loop on renovation led to team clashes. **Suggestions:** Improve upward communication; management listening increases team effort.	**Types:** Respectful work culture; listen and support each other. **Impact:** Respectful comms maintains morale, affects commitment. Body language conveys urgency. **Suggestions:** Recognition platforms (Employee of the Month, verbal praise) for positive comms loop.

9.	**Types:** Face-to-face preferred for small team; keeps things simple. **Impact:** One-on-one clarifies urgent requests; misunderstandings reduce efficiency, cause friction. **Suggestions:** Centralized whiteboard/dashboard for real time task progress.	**Types:** Emails acceptable; walkie talkies/desk visits faster for logistics. **Impact:** Stock freeze due to uncommunicated policy change resulted in canceled requests, damaged credibility. **Suggestions:** Be clearer about goals.	**Types:** Tight-knit team, respectful, trust. **Impact:** Clear comms/appreciation from supervisors keep team motivated. Blame avoided publicly. **Suggestions:** Informal tea-talk sessions with supervisors for more open comms.

CONCLUSION

In conclusion, this study aimed to investigate the impact of effective communication on employee performance among facilities management staff in healthcare settings. The qualitative research approach, utilizing semi-structured interviews, provided valuable insights into the role of interpersonal, organizational, and cultural aspects of communication in influencing team performance, productivity, decision-making, and problem-solving abilities. The findings highlighted the significance of open and respectful communication, streamlined channels, a collaborative organizational culture, and strategies such as training, visual aids, and feedback mechanisms in fostering effective communication and enhancing employee performance. The study's outcomes have the potential to inform the development of improved communication policies and workforce development strategies within the facilities management sector, ultimately contributing to operational efficiency and high-quality patient care in healthcare facilities.

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Impact of Flexible Working Arrangements (FWAs) Towards Facilities Management (FM) Company

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ABSTRACT

This research explores the *Impact of Flexible Working Arrangements (FWAs) on Facilities Management (FM) Companies*, particularly in adapting to modern work trends that influence space usage, employee experience, and overall operational performance. With the growing implementation of remote work, hybrid setups, and flexible schedules, FM companies face the need to modify traditional facility practices. Changes in office occupancy patterns have led to challenges such as inefficient space use, shifting service demands, and the need for more adaptive strategies in managing cleaning, energy, and security operations. The aim of this study is to formulate effective strategies that support better space utilization, improve employee satisfaction, and maintain smooth operations in FWAs-based environments. A qualitative research method was used, involving in-depth interviews with nine participants from three FM companies operating in Kuala Lumpur. The data was examined through content analysis of the interview transcripts and relevant documentation. The results highlight that FWAs have a considerable impact on the way FM services are delivered, requiring more flexible and innovative approaches. The study presents valuable insights and strategic recommendations for FM professionals to enhance their readiness and resilience in managing facilities under flexible work models, ultimately supporting a more sustainable and people-cantered workplace.

Keywords: flexible-working-arrangements, facilities, management, cost-effective, building.

1.0 INTRODUCTION

1.1 Background Issue

Flexible Working Arrangements (FWAs), such as remote work, flexible hours, and hybrid models, have gained prominence due to technological advancements and post-pandemic workplace changes. These arrangements aim to improve productivity, employee satisfaction, and work-life balance, but also present challenges for facility management companies, such as managing physical infrastructure, optimizing space, and maintaining efficiency (Farhana Jamaludin et al., 2024). Issues like limited on-site staff, reliance on digital tools, and team cohesion complicated operations. Empirical research on FWAs' impact on FM performance is limited, particularly in emerging markets like Malaysia (Sanders & Karmowska, 2020).

1.1.1 Problem Statement

Flexible working arrangements (FWAs) are a crucial strategy for facilities management companies to address issues like employee turnover, job satisfaction, and performance. Research shows that FWAs can increase job satisfaction, reducing turnover intentions, especially for the new generation of employees who prioritize work-life balance. They also positively impact on employee performance, fostering a more adaptable and motivated workforce (Farhana Jamaludin et al., 2024). However, FWAs also present challenges like work intensification and blurred boundaries between work and home life. Proper management can overcome these challenges, leading to increased employee retention and reduced overhead costs (Haziq et al., 2023).

1.2 Aim and Research Objective

1.2.1 Aim

The aim of this research are to develop strategies for optimizing space utilization, enhance employee experience, and improve operational efficiency in the context of flexible work arrangements.

1.2.2 Research Objective

The objectives of this research are:

i. To identify the impact of Flexible Working Arrangements (FWAs) on Facilities Management Companies.
ii. To analyze the impact of Flexible Working Arrangements (FWAs) on Facilities Management Companies.
iii. To recommend strategies to optimize space utilization and enhance employee experience in Flexible Working Arrangements (FWAs) environments.

2.0 LITERATURE REVIEW

Flexible Working Arrangements (FWAs) have grown more common in modern organizations, thanks to technological improvements and the global COVID-19 epidemic. These arrangements, which include remote work, flexible hours, and hybrid models, give employees greater control over how, when, and where they work. As firms continue to embrace FWAs, considerable modifications in facilities management (FM) practices are unavoidable (Farhana Jamaludin et al., 2024).

2.1 Literature Review

2.1.1 Flexible Working Arrangements (FWAs)

Flexible working arrangements (FWAs) have evolved significantly over the past decade due to technological advancements and changing employee expectations (Poh et al., 2022). The COVID-19 pandemic has accelerated their adoption, leading businesses, particularly facility management (FM), to rethink office spaces (Einola et al., 2023). FWAs offer cost-saving opportunities but also demand new approaches to staffing, space utilization, and service delivery (Purnakara & Erlina, 2023). To thrive, FM companies must embrace technology, optimize space, and adapt workforce management strategies. Flexible work models (FWAs) are transforming traditional office spaces, forcing facilities managers to adapt their approaches. FWAs increase employee productivity, promote work-life balance, and reduce real estate expenses (Henry Chin and Emma Buckland, 2021). However, they also lead to underutilized office space, increased reliance on digital technology, and the need for flexible facility services (Jamaludin et al., 2024). Hot-desking is becoming more popular to maximize space utilization, and technology-driven solutions like occupancy sensors and AI-powered workplace management systems are crucial for efficient office space usage (Kröll et al., 2017).

2.1.2 Facilities Management (FM) in Flexible Working Arrangements (FWAs)

Facilities management (FM) plays a crucial role in building efficiency and occupant well being. The adoption of Flexible Working Arrangements (FWAs), such as remote work and hybrid models, has necessitated significant changes in FM practices (FMANZ, 2019).

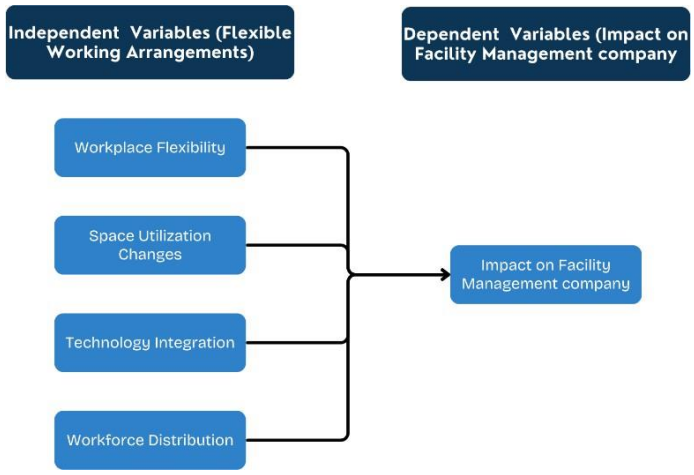
2.1.2.1 Impact of FWAs and FM on organization

Facilities management involves various operations and services to optimize physical settings, including office space, safety, infrastructure, and work experience, aiming to help organizations achieve operational efficiency and strategic goals (Hasim et al., 2020). FWAs can enhance employee satisfaction and productivity by providing more autonomy and reducing commute time. They can also help organizations build resilience by allowing them to operate even during disruptions (Einola et al., 2023). However, successful adoption requires addressing issues like teamwork preservation, remote staff management, and data security. Facilities Management practices, particularly in office environments, are impacted by FWAs, necessitating a reassessment of space utilization techniques and modifications to cleaning protocols, energy management strategies, and maintenance schedules (Talib et al., 2023).

2.2 Research Conceptual Framework

Figure 1 shows how this research examines the influence of Flexible Working Arrangements (FWAs) on operational outcomes in facility management companies, focusing on space utilization, employee experience, and efficiency. It identifies independent variables like workplace flexibility, space utilization changes, technology integration, and workforce distribution, which influence dependent variables like operational efficiency, employee experience, space utilization optimization, and service delivery quality. Understanding these relationships can help optimize space, enhance employee satisfaction, maintain service quality, and improve operational efficiency.

Figure 1 Conceptual Framework



3.0 METHODOLOGY

3.1 Research Design

The researcher's design, based on Taherdoost's theory (2022), serves as a guide for determining the best methodology for this study. It determines the method's approach and appropriate statistical test for data analysis. The research onion (Tengli, 2020), a systematic approach, starts with philosophical considerations and narrows down to specific methods and techniques. Each layer must align with research objectives for coherence and rigor. By peeling back layers, researchers can create a robust framework tailored to their specific needs.

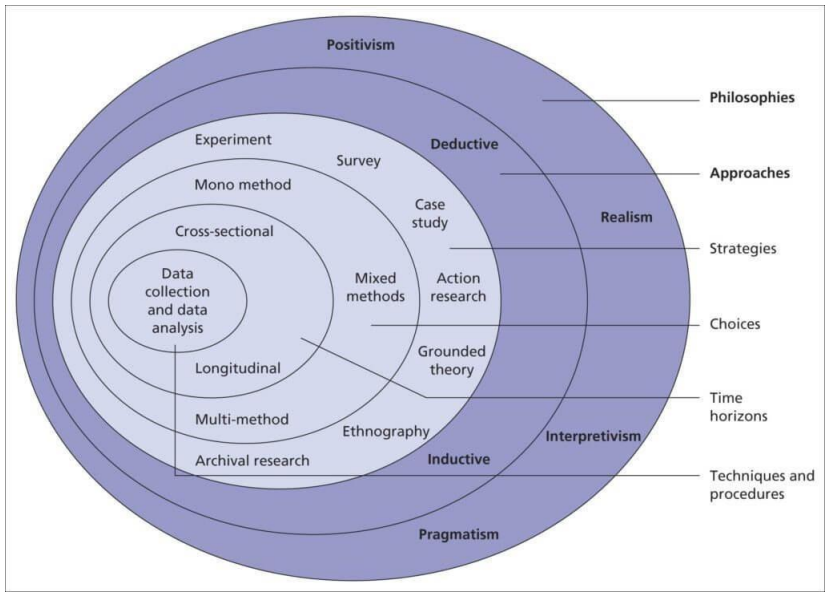


Figure 2 Research Onion

3.1.1 Philosophy (Interpretivism and Constructivism)

Interpretivism and Constructivism are research philosophies in qualitative studies, emphasizing the subjective nature of reality and understanding how individuals interpret their social worlds. Interpretivism focuses on understanding human behaviour from the perspectives of participants, while constructivism emphasizes knowledge construction (Tengli, 2020).

3.1.2 Research Approach (Induction)

The inductive approach to research collects detailed data through interviews, observations, or document analysis, identifying patterns and themes to develop a theoretical framework. It is useful for understanding human experiences and supports the complexity of qualitative data (Tengli, 2020).

3.2 Data Collection and Instrument

This study will use semi-structured interviews with operational staff in facility management companies that have implemented Flexible Working Arrangements (FWAs) to explore the challenges faced by those managing daily FM tasks under changing work structures. The interviews will focus on topics such as workflow efficiency, team coordination, supervisory challenges, task accountability, and on-site service delivery (Barroga & Matanguihan, 2022). The data collected will be transcribed, coded, and thematically analyzed to identify recurring patterns and emerging themes that can inform future FM strategies. The study aims to provide a deeper understanding of how flexible work structures are reshaping facility management practices. The data collected will be analyzed to identify recurring patterns and inform future FM strategies, providing a deeper understanding of the real-world implications. (Patel, 2019).

3.3 Population and Sample

This study examines the impact of Flexible Working Arrangements (FWAs) on executive-level operational staff in facility management companies. The interviews aim to understand how FWAs affect operational efficiency, communication, and coordination (Creswell, 2018). The research uses a sample of nine participants, ensuring diverse representation from various FM companies. The findings can help develop more responsive and sustainable FM policies and practices under flexible work structures (Taherdoost, 2022). Participants were selected from three

major facility management companies operating under Malaysia's healthcare support services contract, each with HQs located in Kuala Lumpur but supporting hospital operations across different regions:

A. Company A serving hospitals in Negeri Sembilan, Melaka, and Johor:
Participant 1: Head of FEMS, based in HQ and stays in Melaka.
Participant 2: Head of FMS, based in HQ and stays in Seremban.
Participant 3: Head of Mechanical Engineering, based in HQ and stays in Setia Alam.

B. Company B serving hospitals in Pulau Pinang, Kedah, and Perlis:
Participant 4: Head of FEMS, based in HQ and stays in Pulau Pinang.
Participant 5: Head of BEMS, based in HQ and stays in Kedah.
Participant 6: Head of Electrical Engineering, based in HQ and stays in Kuala Lumpur.

C. Company C serving hospitals in Kuala Lumpur, Kelantan, and Terengganu:
Participant 7: Head of BEMS, based in HQ and stays in Kelantan.
Participant 8: Head of FMS, based in HQ and stays in Selangor.
Participant 9: Head of FEMS, based in HQ and stays in Terengganu.

4.0 RESULTS AND DISCUSSION

The interview results address the research objectives and key variables related to the implementation and impact of Flexible Working Arrangements (FWAs) in Facilities Management companies. The interview guide was structured into four sections: Section A (participant demographics), Section B (independent variables focusing on types of FWAs implemented such as hybrid, remote work, and flexible hours), Section C (dependent variables analysing the impact of FWAs through Workplace Flexibility, Space Utilization, Technology Integration, and Workforce Distribution), and Section D (participants' recommendations for improving space optimization, employee experience, and operational efficiency in FWA settings).

4.1 Findings and Analysis

4.1.1 Research Objectives 1: Identify the impact of FWAs on FM Companies.

4.1.1.1 Types of FWAs are implemented

The interviews reveal that Flexible Working Arrangements (FWAs) have notably impacted FM companies at various levels. Participants described different FWA types: hybrid models (P1, P5, P8), remote work (P4, P7, P9), and flexible hours (P2, P3, P6). These improved executive autonomy and efficiency. For example, P1 said the hybrid model enabled quicker site decisions; P2 found staggered hours enhanced urgent response; P5 valued the focused time for strategic work. Challenges included digital literacy gaps (P3, P5), poor rural internet connectivity (P1, P2, P7), and reduced team cohesion (P8, P9). Still, most participants agreed that FWAs boosted productivity, decision-making, and regional operations.

4.1.2 Research Objectives 2: Analyze the impact of FWAs on FM Companies.

4.1.2.1 Workplace Flexibility

Workplace flexibility, through remote work, staggered hours, and hybrid models has improved productivity and responsiveness in FM teams. Participants (P1, P2, P4, P5) noted that tasks like reporting, planning, and data analysis were easier to manage with fewer distractions and more schedule control. P1 said remote work helped engineers focus on detailed planning, while P5

mentioned faster strategic decisions due to digital tools. However, P3 and P6 pointed out that technical roles still required on-site presence. Still, flexible hours (P2, P6) allowed better integration of site and admin duties. P8 added that autonomy increased job satisfaction. Overall, flexibility enhanced non-physical task performance but needed to be balanced with in-person work requirements.

4.1.2.2 Space Utilization Changes

FWAs have changed how office and facility spaces are used, with reduced daily attendance at HQ reported by P1, P2, P3, P4, and P8 leading to underused desks and meeting rooms. Participants suggested adopting shared spaces like hot-desking (P1, P2), collaboration zones (P2, P5), and multipurpose technical stations (P3, P6). P4 and P7 advocated flexible, activity based layouts, while P7 and P8 recommended desk booking systems and smart analytics for space optimization. P3 and P9 proposed dedicated rooms (e.g., CAD stations, innovation labs) for specific technical tasks. Overall, participants agreed that fixed workstations no longer suit FWA environments, favouring modular, task-based spatial design instead.

4.1.2.3 Technology Integration

Technology was seen as essential to enabling FWAs, with tools like Microsoft Teams, Zoom, and CMMS widely used for remote work (P1, P2, P4, P7). Remote diagnostics helped manage on-site assets (P1, P5, P9). However, challenges arose: P1 and P7 cited unstable rural internet; P3 noted resistance from senior staff to adopt new platforms. Other concerns included cybersecurity (P4), software compatibility (P6), and system integration issues (P8). To address these, P6 and P7 recommended standardized software, strong IT support, and ongoing training. Despite obstacles, all participants agreed that technology remains vital for effective and flexible operations.

4.1.2.4 Workforce Distribution

FWAs allowed for a more decentralized FM workforce, with executives and senior engineers positioned closer to hospitals or field sites (P1, P5, P7, P9), improving site responsiveness. P9 highlighted faster decisions due to leadership presence in Terengganu, while P4 and P7 noted benefits to localized leadership and client relations. However, P2, P4, and P8 observed reduced informal communication and team cohesion. To address this, structured communication tools and virtual engagement were recommended. P3 and P9 emphasized the need for digital mentoring and collaboration hubs. Overall, decentralization enhanced local service but required stronger systems for maintaining cohesion and knowledge-sharing.

4.1.3 Research Objectives 3: Strategies and Recommendations.

4.1.3.1 Optimize space utilization

To optimize space use under FWAs, participants from all three companies recommended shifting from fixed desks to hot-desking (P1, P2, P3) and introducing shared technical workstations for tasks like CAD and diagnostics (P3, P6). Activity-based layout zones for collaboration, focus, and hybrid meetings that were also favored (P4, P5, P8). Smart office tools and desk booking systems were suggested to enhance space management (P7, P8). Additionally, establishing innovation labs or regional satellite hubs was proposed to reduce HQ travel (P5, P9). Overall, these strategies aim to align office setups with flexible and dynamic work patterns.

4.1.3.2 Enhance employee experience and engagement

To enhance employee experience in flexible work settings, participants stressed the need for strong communication and team bonding through online check-ins, virtual town halls, and

informal video chats (P1, P2, P4). Mental health and wellness support, including ergonomic home setups and flexible benefits, were also emphasized (P2, P4, P7). Structured virtual mentorship and recognition of both remote and on-site contributions via appraisals were seen as essential (P4, P5, P9). P6 and P8 highlighted the need for clear career development for hybrid staff, while ongoing learning and peer knowledge-sharing were recommended to boost engagement and growth (P3, P5, P7).

4.1.3.3 Improve operational efficiency

To improve operational efficiency while balancing FWAs and on-site demands, participants suggested adopting advanced technologies like AI-driven predictive maintenance (P1, P3, P5) and remote diagnostics with centralized dashboards (P5, P9). Robust communication systems were recommended to ensure quick issue escalation between remote and on-site teams (P6, P9). Standardizing digital workflows and documentation was seen as key to maintaining coordination (P2, P8). Additionally, cross-training on-site staff to handle diverse tasks independently was proposed to reduce dependence on HQ (P7, P9). These strategies aim to align remote flexibility with reliable delivery service.

4.2 Summary of Findings and Analysis

Table 1 shows the Summary of Findings and Analysis for this research

Sub-Objective	***Theme / Focus Area***	***Key Findings***	***Supporting Participants***
D1.1: Strategies to optimize space utilization in FM companies adopting FWAs	Hot-desking & Shared Workspaces	Transition from fixed desks to hot-desking and shared technical workstations to reduce underutilized office space.	P1, P2, P3, P6, P9
	Activity-Based Layouts	Design flexible workspaces such as collaboration zones, focus pods, and hybrid meeting rooms.	P2, P4, P5, P7, P8
	Smart Office Systems	Use desk booking platforms and space utilization data to monitor and optimize HQ layouts.	P7, P8
	Satellite Hubs & Innovation Labs	Develop regional hubs or labs to minimize travel and support decentralized teams.	P5, P9
D1.2: Strategies to enhance employee experience and	Virtual Engagement	Hold structured online check-ins, town halls, and informal team activities to promote	P1, P2, P4

engagement in a flexible working environment		communication and bonding.	
	Wellness & Mental Health	Provide ergonomic home support, flexible benefits, and mental wellness programs.	P2, P4, P7
	Mentorship & Recognition	Encourage virtual mentorship and implement transparent recognition and appraisal systems.	P4, P5, P9
	Career Development & Learning	Support hybrid staff with clear growth paths and online learning platforms.	P3, P6, P7, P8
D1.3: Recommendations to improve operational efficiency under FWAs while meeting on-site commitments	Predictive Maintenance & AI	Use data analytics and AI for predictive maintenance to reduce unplanned visits.	P1, P3, P5
	Remote Diagnostics & Dashboards	Implement remote monitoring tools and centralized dashboards for asset management.	P5, P9
	Communication Protocols	Establish strong remote-to-site communication systems and escalation workflows.	P6, P9
	Workflow Standardization	Digitize and standardize documentation and processes for consistency.	P2, P8
	Cross-Training On-site Teams	Train on-site personnel to handle broader tasks to improve self-reliance and reduce HQ dependency.	P7, P9

5.0 CONCLUSION

This study confirms that Flexible Working Arrangements (FWAs), primarily hybrid models and flexible hours, significantly impact Facilities Management (FM) companies across multiple dimensions. The research revealed that FWAs generally enhance workplace flexibility, leading to improved productivity for certain tasks and greater employee autonomy. However, they also necessitate a fundamental shift in how physical spaces are utilized, resulting in less consistent office occupancy and a growing need for collaborative zones and flexible desk management. Furthermore, technology integration is critical, while enabling remote operations, it also introduces challenges related to connectivity, cybersecurity, and digital literacy that FM companies must address.

The data further demonstrates that FWAs transform workforce distribution by enabling geographically dispersed teams and leadership, which assists in talent attraction but requires new strategies to maintain team cohesion and facilitate knowledge sharing. These insights underscore the necessity for FM companies to proactively adapt their strategies. Practical implications include implementing dynamic space management, investing in robust technological infrastructure, developing strategic workforce planning for distributed teams, and prioritizing employee well-being through targeted initiatives.

In conclusion, this research serves as a vital guide for FM companies navigating the evolving landscape of flexible work, offering actionable strategies to optimize operations and enhance employee satisfaction. It also lays the groundwork for future research, suggesting further quantitative studies on ROI, explorations into the long-term impacts on organizational culture and employee retention, and investigations into advanced technological applications like AI and analytics within FWA contexts.

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Occupants' Satisfaction Towards Indoor Environment Quality in Commercial Building

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ABSTRACT

Indoor Environmental Quality is crucial to the comfort, health, and productivity of commercial building workers. This study aims to enhance occupant satisfaction with indoor environmental quality to promote the well being and health of employees in optimal conditions. The primary objectives are to identify the factors influencing the indoor environment quality in commercial buildings, to evaluate the occupants' satisfaction and to recommend strategies for improving indoor environmental quality in commercial buildings. A quantitative methodology will be implemented, using questionnaire surveys as data collection instruments, and the sampling technique used is stratified random sampling and based on Krejie and Morgan table with a sample size of 201 respondents. Air comfort, thermal comfort, visual comfort and acoustic comfort will be assessed using statistical analysis to establish satisfaction and opportunities for improvement in the indoor environment. Using the statistics and survey software IBM SPSS Statistics version 27 also facilitates the analysis of descriptive statistics, frequency distributions, mean scores, and Cronbach's Alpha reliability tests, to determine satisfaction of occupants with precision and efficiency. The findings showed that occupants satisfied with certain aspects of their indoor environment which is air comfort and visual comfort were in high level mean scores and thermal comfort and acoustic comfort were in medium level mean scores. This research should give building managers and designers actionable understandings to optimise information and enhanced indoor environment quality (IEQ) to promote a healthier and more productive workplace.

Keywords: indoor, environment, quality, commercial, building

1.0 INTRODUCTION

1.1 Research Background

In psychological and physiological research, "comfort" and "Indoor Environment Quality" (IEQ) relate to the integration of acoustics, temperature conditions, visual, and Indoor Air Quality (IAQ) via a mechanically controlled heating/cooling ventilation system. (Ganesh et al., 2021). The ability of a building's interior environment to maintain the productivity, well-being, and health of its occupants is a measure of its quality. "Indoor air quality" encompasses all aspects of a building's indoor air quality, including those that affect tenant comfort and health. The significance of indoor environmental quality in commercial and institutional buildings is acknowledged by building services managers and M&E engineers (Mahyuddin & Law, 2019). The health and well-being of inhabitants are significantly impacted by indoor surroundings. Tenants in a building that is healthy and conducive are content and productive. (Al Horr et al., 2017). Numerous research (Ramly & Mahamad, 2023)show that a number of factors, including the surrounding environment, the building's features, and the characteristics of the tenants, affect occupant comfort. Many office workers report occupational health issues, which are frequently connected to symptoms of sick building syndrome (SBS). The incidence of SBS symptoms may be impacted by building attributes such high interior temperatures, intense lighting, inadequate ventilation, air pollution, and inadequate cleaning (Felgueiras et al., 2023). Human health is at risk from mould infestation and humidity problems (Mirzaei et al., 2020).

In this particular study, Residents were rather pleased with the lights, but they weren't as happy with the thermal comfort. The presence of daylight causes a larger exchange of heat with the interior environment, which raises the temperature inside, according to one theory explaining this occurrence (Esfandiari et al., 2021).

1.2 Research Aim

To enhance occupant satisfaction with indoor environmental quality to promote the well being and health of employees in optimal conditions.

1.3 Research Objective

- To identify the factors influencing the indoor environment quality in commercial buildings.
- To evaluate the occupants' satisfaction with indoor environment quality in commercial buildings.
- To recommend strategies for improving indoor environmental quality in commercial buildings.

2.0 LITERATURE REVIEW

2.1 Occupant Satisfaction

Numerous investigations have been conducted to examine the influence that the indoor environment has on each resident's efficiency and production (Asojo et al., 2021). Kamaruzzaman et. al (2018) noted that the results of the questionnaire survey should help identify specific aspects of the environment that need to be developed and adjusted in order to provide a better interior environment for residents. Post-occupancy evaluation, or POE for short, is the process of assessing a building's performance after it has been occupied (Nawawi & Khalil, 2008). Several studies have claimed that compared to people who live in traditional buildings, residents of green buildings report better levels of satisfaction and a healthier lifestyle (Esfandiari et al., 2021). One important indicator for assessing the functionality and performance of constructed settings is occupant happiness. Numerous Indoor Environmental Quality (IEQ) elements, including lighting, acoustics, air quality, and thermal comfort, have an impact on it (Kim & de Dear, 2013). Achieving a high degree of occupant satisfaction, especially in commercial buildings, promotes productivity and energy efficiency in addition to well-being (Frontczak & Wargocki, 2011). Khoshbakht et al. (2018) suggested an approach that emphasises the significance of user-centred design in sustainable architecture by connecting green building features to perceived quality and satisfaction. In a post-occupancy assessment of student accommodation, (Umar et al., 2025) emphasised the impact of air circulation and thermal comfort on students' subjective happiness. These findings are consistent with (Ai & Mak, 2016), who highlighted how perceived control over one's surroundings affects one's level of contentment.

2.2 Thermal Comfort

"The condition of mind, which expresses satisfaction with the thermal environment" is how ISO Standard 7730:2005 defines thermal comfort (Zuhari & Sheau-Ting, 2019). According to Yusoff & Ja'afar (2019), A location's thermal comfort significantly affects productivity, health, and human performance. Consequently, it is a crucial concern in the design and operation of a building. Some definitions of "thermal comfort" include "the state of mind that expresses satisfaction with the thermal environment." (Al-Absi et al., 2022). Nicol & Humphreys (2002) proposed the adaptive thermal comfort model, which postulates that residents of buildings with natural ventilation are more satisfied because they can adjust to a larger range of temperatures.

In Malaysia, the general level of occupant happiness in commercial buildings is greatly influenced by thermal comfort. Thermal comfort is described as "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE, 2021). Thermal comfort has a big impact on productivity, happiness, and health (Abdulaali et al., 2025). A psychological state that expresses contentment with the thermal environment through a subjective evaluation is known as thermal comfort in a built environment (Md Taib et al., 2023). Previous studies examining the connection between indoor environmental quality and worker productivity has indicated that worker productivity is significantly impacted by the thermal environment. (Kawakubo et al., 2023). It should be recognised that skin temperature monitoring has limitations even though it can provide important insights into occupants' thermal comfort, wellbeing, and productivity (Suryo et al., 2024).

2.3 Visual Comfort

The level of light transmission and glare in a building is defined as an indicator of visual comfort. (Khairuddin & Denan, 2024). The measuring of light intensity and illuminance level is necessary to guarantee that a room has reached the necessary degree of visual comfort. Stated differently, the amount of light that a surface receives (Wienold, 2009). According to Saint Gobain (2020), both too little and too much light can cause visual discomfort. Visual comfort is usually a subjective response to light amount and quality in a room. Subjects rarely report visual discomfort in well-lit spaces. (Mahindra-TERI, 2021). The concept of visual comfort depends on our ability to control the light levels around us (Tan & Abdul Majid, 2022). Numerous studies are showing that daylight is the best source of brightness for improving health, well-being, and efficiency in the workplace. Natural sunlight is a more stable and changing source of light that helps keep circadian rhythms in balance, boosts mood, and makes brain work better (Lim et al., 2017). Visual comfort is comprised of a variety of aspects, including the intensity, distribution, and quality of light, as well as the reduction of glare and shadows(Tan & Abdul Majid, 2022). When lighting is well-controlled, people can focus better, get more done, and stay healthy in general. Students are more likely to stay interested, focused, and relaxed if they are in a room with the right amount of light. In turn, this makes them better able to learn and helps their schoolwork (Eleyan et al., 2021). On the other hand, the design of lighting systems must also take into account aspects such as energy efficiency (Kwong, 2020).

2.4 Acoustic Comfort

The significance of carefully complementing the auditory environment throughout the design phase in order to produce a well-balanced soundscape that is capable of supporting both collaborative and private activities (Amira Binti Abd Jalil, 2018). Tasks involving listening or auditory processing experience a substantial decrease in performance when exposed to high noise levels or, conversely, an overly quiet environment (Selamat & Zulkifli, 2016). Beyond auditory effects, noise exposure can also cause non-auditory effects such as stress, fatigue, and reduced overall well-being (Selamat & Zulkifli, 2016). The auditory environment is not merely a backdrop but rather an active component of the dynamics that occur in the workplace (Purushothama Rao et al., 2012). The acoustic environment is significantly influenced by four typical methods: natural ventilation, daylight harvesting, limited usage of finishes, and open plan office layouts (Jalil et al., 2016) The soundproofing rules for open-plan offices were summarised up by Virjonen et al. (2009) and Keränen & Hongisto (2013), they include using big areas that absorb sound, high screens and enclosures between workstations, and enough sound masking all at the same time (Hongisto et al., 2016).

2.5 Air Comfort

The idea that indoor air quality (IAQ) is regulated by a dynamic interaction of elements is highly valued by the scientific community (Saini et al., 2020). A increasing concern in the built environment is sick building syndrome (SBS), especially in urban and workplace settings where individuals spend a lot of time indoors (Sarkhosh et al., 2021). People's behaviour and emotions when they are in interior environments can be directly impacted by poor indoor air quality (Ramly & Mahamad, 2023). Building owners, companies, and the general public may incur large expenses as a result of an inappropriate interior climate. Reduced productivity and actual medical expenses are the main expenditures linked to indoor climate (Staveckis & Borodinecs, 2021). Omrani et al. (2021) mentioned that employing portable and ceiling fans can aid in air circulation, creating a steady flow that improves comfort without appreciably changing indoor temperatures. Damiati et al. (2016) in their findings, the mean comfort temperature rose as air circulation increased. Using natural wind and fans, several studies in tropical and warm-humid conditions have shown that occupants remained comfortable in naturally ventilated buildings. Candido et al. (2010) combined the percentages of thermal and air movement acceptability to evaluate occupant comfort. They discovered that around 90% of thermal acceptability matched the ASHRAE adaptive comfort standard's projections. Residents did, however, indicate a need for "more air velocity." The comfort of the residents is correlated with how they perceive air movement (Liu et al., 2018).

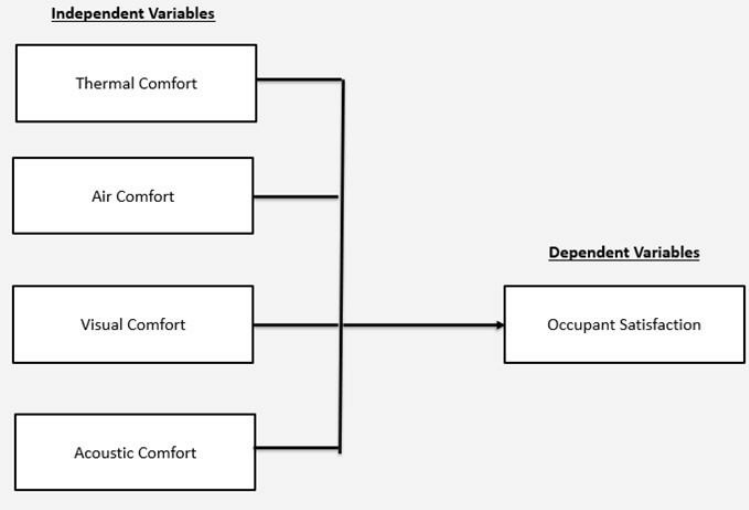

Figure 1: Flow chart of methodology process.

3.0 METHODOLOGY

According to Creswell (2014), Positivism emphasises objective truth, knowledge from observable and measurable facts, and scientific research. Bryman (2016) defines deduction as a research method that starts with a theory or hypothesis and then develops a plan to test it through empirical observation and analysis. An outline of the research design that was used in this study was positivism, which served as the research philosophy, and deduction, which served as the research approach. Creswell (2014) defines quantitative research as an approach for testing objective theories by examining the relationship among variables, which are measured using instruments and analyzed with statistical procedures. Kumar (2011) explains that stratified random sampling is used when the population is composed of different subgroups or strata, and researchers want to ensure that each subgroup is adequately represented in the sample. A quantitative research design serves as the basis for this study, and the method of sampling that was utilised was stratified random sampling. Krejcie (1970) developed a formula

and accompanying table for determining appropriate sample sizes for given population sizes, commonly used in social science research to ensure representativeness and statistical validity. The sample size consisted of 201 individuals that participated in the study. Fink (2013) explains that questionnaires are essential instruments in survey research, providing a structured means to collect quantitative data from respondents systematically. An instrument that is utilised in this research to collect the data is the distribution of a questionnaire to the individuals who participated in the study. Questionnaire has three important components. Section A collects demographic data. Section B assesses occupant satisfaction with air, thermal, visual, and acoustic comfort. Each aspect is rated from 1 (extremely unsatisfied) to 5 (very satisfied). Finally, Section C allows respondents to choose three indoor environmental quality improvement recommendations. According to Zikmund et al. (2010), descriptive analysis provides concise summaries and visualisations of data in a study, forming the basis of almost all quantitative analysis. This study will evaluate commercial building tenants indoor environmental quality satisfaction by asking questions about it in each office and using descriptive analysis. One-hot encoding converts categorical data to binary matrices (Geron, 2019). Each category value is converted into a binary column and assigned a 1 or 0 to indicate its presence or absence. This method was used to find the respondent's most preferred suggestion in Section C questions using frequency. It achieved the third goal, to recommend strategies for improving indoor environmental quality in commercial buildings.. Using the software for surveys and statistics known as IBM SPSS Statistics is also helpful in swiftly and accurately analysing the findings and discussion of big datasets in the form of questionnaires.

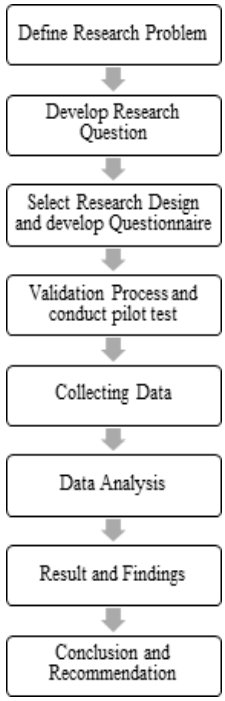

Figure 2: Flow chart of methodology process.

This flowchart shows research methodology. Define the research challenge to create a targeted research topic. After choosing a study design, a questionnaire is created. To ensure reliability, the questionnaire is validated via a pilot test. After validation, data is collected and analysed to understand results. Final conclusions and recommendations are drawn from the research results after summarising them. This systematic strategy promotes thorough and reliable research.

Table 1 Reliability Coefficients pilot test for Each Variable (N=40)

Variables	No. of Items	Item Deleted	Cronbach's Alpha
Air Comfort	6	-	0.923
Thermal Comfort	5	-	0.850
Visual Comfort	6	-	0.891
Acoustic Comfort	5	-	0.840

4.0 RESULTS AND DISCUSSION

Table 2 The respondent's profiles for this study

		Frequency	Percentage%
Gender	Female/Wanita	110	54.7%
	Male/Lelaki	91	45.3%
Occupy office	Akedemi Sains Malaysia (ASM)	71	35.3%
	Malaysia Productivity Corporation (MPC)	115	57.2%
	NAICO	15	7.5%
Age group	24 years and below	57	28.4%
	25 – 34 years	71	35.3%
	35 – 44 years	55	27.4%
	45 – 54 years	18	9.0%
Time Spent In The Office per day	2 – 4 hours	19	9.5%
	5 – 7 hours	44	21.9%
	Less than 2 hours	10	5.0%
	More than 7 hours	128	63.7%

There were 201 participants in all, with 54.7% of them being women and 45.3% being men. The Malaysia Productivity Corporation has the largest percentage of respondents which is 57.2%, followed by Akademi Sains Malaysia is 35.3% and NAICO is 7.5%. The majority of people are between the ages of 25 and 34 years 35.3%, followed by those between the ages of 24 and below is 28.4%, 35 to 44 is 27.4%, and 45 to 54 years is 9.5%. More than half, 63.7% report spending more than seven hours a day in the office, compared to smaller percentages who claim five to seven hours is 21.9%, two to four hours is 9.5%, and less than two hours is 5.0%.

4.1 DESCRIPTIVE ANALYSIS

The descriptive statistics were also calculated for each item and variable to investigate their level among the respondents. The three levels of categories according to the mean consist of low (1.00 – 2.33), medium (2.34 -3.67), and high (3.68 – 5.00) (Mohamad Najib Abdul Ghafar, 2013).

Table 3 Descriptive Statistics for Variables

Descriptive Statistics				
	N	Mean	Std. Deviation	Level
Air Comfort	201	3.838	0.6743	High
Thermal Comfort	201	3.598	0.7568	Medium
Visual Comfort	201	3.797	0.7189	High
Acoustic Comfort	201	3.350	0.7112	Medium

Descriptive analysis indicated that respondents expressed the most satisfaction with air comfort (M = 3.84) and visual comfort (M = 3.80), both categorised as "High". Thermal comfort (M = 3.60) and auditory comfort (M = 3.35) were assessed at a "Medium" level, signifying moderate satisfaction and opportunities for enhancement.

4.2 SECTION C ANALYSIS

Table 4 Frequencies for recommendations

Frequencies Statistics				
Recommendations	**N**	**Mean**	**Frequency**	**Percent**
Q1: Conducting regular IEQ assessments and improvements.	201	0.5771	116	57.7%
Q2: Implementing workplace policies for a healthier indoor environment.	201	0.3881	78	38.8%
Q3: Educating employees on maintaining indoor comfort.	201	0.3284	66	32.8%
Q4: Encouraging feedback on IEQ concerns.	201	0.5124	103	51.2%
Q5: Establishing green building certifications and standards (e.g., LEED, WELL).	201	0.3532	71	35.3%
Q6: Investing in smart building technologies for IEQ monitoring.	201	0.3383	68	33.8%
Q7: Promoting flexible workspace design for better occupant comfort.	201	0.5025	101	50.2%

According to Figure 2, the most selected strategy was Q1: Conducting regular IEQ assessments and improvements, chosen by 57.7% of respondents. This was followed by Q4: Encouraging feedback on IEQ concerns – 51.2% and Q7: Promoting flexible workspace design – 50.2%. The remaining strategies received lower percentages which is Q2: Implementing workplace policies for a healthier indoor environment – 38.8%, Q5: Green building certifications and standards – 35.3%, Q6: Smart building technologies for IEQ monitoring – 33.8% and Q3: Educating employees on maintaining indoor comfort – 32.8%. These results show that respondents prefer practical and people-focused strategies, such as regular assessments, feedback opportunities, and flexible workspaces. Strategies involving policy, education, or technology were less favoured, possibly due to limited awareness or indirect impact on daily comfort.

5.0 CONCLUSION

The purpose of this study was to enhance occupant satisfaction with indoor environmental quality to promote the well being and health of employees in optimal conditions. The following variables were evaluated visual comfort, thermal comfort, acoustic comfort and air comfort. The study also investigated the respondent's favoured methods for raising IEQ using well organised suggestions. A total of 201 responses were collected and analyzed using descriptive statistics. Air comfort and visual comfort achieved the highest satisfaction ratings, with mean scores of 3.84 and 3.79. These were designated as having a "High" satisfaction level, signifying that occupants typically see the air quality and lighting conditions in the buildings as satisfactory. Thermal comfort (M = 3.60) and acoustic comfort (M = 3.35) were assessed at a "Medium" level, indicating potential enhancements in temperature stability and sound management. In Section C, the most preferred strategies to improve IEQ were Conducting regular IEQ assessments and improvements (57.7%) Encouraging feedback on IEQ concerns (51.2%) Promoting flexible workspace design (50.2%). Buildings should maintain regular monitoring and assessment of IEQ conditions to ensure long-term occupant comfort. Occupant feedback should be actively collected and integrated into facility management practices. Flexible workspace design should be considered in future renovations or new developments to support occupant well-being. In conclusion, this study confirmed that occupants in the selected commercial buildings are generally satisfied with the current indoor environmental conditions. However, continuing efforts are necessary to sustain and enhance this quality. By focusing on regular assessments, encouraging feedback, and providing adaptive, comfortable workspaces, organizations can significantly improve occupants' satisfaction and overall indoor environmental performance.

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The Challenges of Facilities Maintenance Management Toward Efficient Operation at Healthcare Facilities

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ABSTRACT
Healthcare facilities represent complex operational environments where efficient facility maintenance management is critical to ensuring patient safety, operational continuity, and infrastructure reliability. This research examines the multifaceted challenges facing facilities maintenance management in healthcare settings. This research aims to suggest effective strategies for addressing and mitigating the challenges that hinder operational efficiency in healthcare facilities, with a focus on facilities maintenance management. The primary objectives are to identify and analyze facility maintenance management challenges and recommend improvements to enhance healthcare operations. To examine these concerns, a qualitative methodology was employed, involving semi-structured interviews with facility managers, executive-level FEMS heads, and engineers. The data collected was analyzed by using content and thematic analysis to extract recurring patterns and insights. The findings indicated that insufficient planning, budget allocation, the absence of skilled staff, poor communication, and the restricted utilization of digital tools are significant obstacles to effective maintenance management. These challenges contribute significantly to operational inefficiencies within healthcare settings. The study concludes that the adoption of structured maintenance protocols, investment in staff training, and the integration of technology-driven solutions are crucial in enhancing maintenance practices and, consequently, improving the overall efficiency and quality of healthcare service delivery.

Keywords: facilities, maintenance, management, operation, healthcare

1.0 INTRODUCTION

1.1 Research Background
Healthcare facilities are complex environments that require meticulous maintenance management to ensure efficient operations and high-quality patient care. (Laksono et al., 2022.) It also represents complex and dynamic environments where infrastructure maintenance plays a critical role in ensuring patient safety, operational continuity, and quality of care. The increasing complexity of medical technologies, evolving regulatory requirements, and rising operational costs have created unprecedented challenges in facilities maintenance management. According to Osunsanmi et al. (2022), their study demonstrated that facilities with robust maintenance management strategies were better equipped to respond to unexpected challenges, adapt to rapidly changing conditions, and maintain continuous patient care. Despite growing demands and complexity, many hospitals still face challenges due to inadequate maintenance strategies. Rising populations, urbanisation, and stricter compliance requirements have made maintenance both essential and costly (Bakri et al., 2021; Yousefli et al., 2019). To meet these challenges, healthcare facilities must adopt innovative, data-driven approaches that enhance efficiency, ensure safety, and support uninterrupted care delivery.

1.2 Aim and Research Objectives
The primary aim of this study is to suggest effective strategies for addressing and mitigating the challenges that hinder operational efficiency in healthcare facilities. This research aims to

investigate the impact of various maintenance management aspects, including work order systems, resource allocation, technological advancements, personnel skills, and communication, on the overall efficiency and functionality of healthcare operations. To achieve this aim, the study has several key objectives.

a. To identify the challenges of maintenance management towards efficient operation at healthcare facilities.

b. To analyse the challenges of maintenance management towards efficient operation at healthcare facilities.

c. To propose recommendations for improving maintenance management systems to enhance the overall efficiency of healthcare operations.

2.0 LITERATURE REVIEW

2.1 Efficient Operation at Healthcare Facilities

Operational efficiency is vital in any organization, particularly in healthcare, where it directly influences patient outcomes, staff performance, and overall service quality. It involves minimizing waste, reducing costs, optimising time, and ensuring that all systems function seamlessly (Ichendu & Irimiagha, 2024). In healthcare settings, efficient operations support the delivery of timely medical services, maintain a sterile and safe environment, and ensure that essential equipment remains functional, primarily since hospitals operate 24/7 (Laksono et al., 2022). This requires continuous process improvement, strong coordination, effective communication, and the strategic use of technology. Additionally, efficient operations help balance high-quality care with cost control, regulatory compliance, and resource management, ultimately enhancing patient satisfaction, staff productivity, and the financial sustainability of the facility.

2.2 The Challenges of Facilities Maintenance Management Towards Efficient Operation

Healthcare facilities face numerous challenges in managing and maintaining their physical infrastructure, which directly affects operational efficiency and patient care. Facilities maintenance encompasses tasks such as repairing, upgrading, and maintaining essential building systems and medical equipment, all of which are vital to ensuring smooth operations. These challenges include limited resources, outdated technology, skill gaps among personnel, and stringent regulatory requirements, all of which are intensified in healthcare settings where equipment reliability and environmental control are critical. As noted by Hussein et al. (2023), the strategic connection between maintenance practices and operational performance is complex, and poor management is often due to unpredictable circumstances, which can significantly disrupt healthcare delivery (Mong et al., 2019). Ultimately, addressing these obstacles is crucial to ensure that healthcare facilities remain safe, functional, and capable of delivering high-quality, uninterrupted care.

3.0 METHODOLOGY

The questionnaire was developed using qualitative research methods, specifically from an interpretive perspective that values complexity and context specificity. This approach explored Facilities Management companies' subjective experiences and perceptions of challenges in facilities maintenance, focusing on achieving efficient operations in healthcare environments.

To develop and validate the interview questions, a multi-step process was followed. Initially, a thorough review of existing literature and prior studies on facility maintenance and operational efficiency in healthcare settings was conducted. Based on this review and feedback from academic supervisors, the interview protocol was refined to ensure clarity, relevance, and comprehensiveness. A head civil engineer from the facility management department also performed one-on-one validation of the questions. His feedback was instrumental in improving the protocol's content, ensuring it aligned with industry standards, and enhancing its reliability and validity.

The final interview guide adopted a semi-structured format**,** offering both flexibility and focus on essential themes. The interviewees included nine (9) key leaders working in concession facility management companies responsible for hospital buildings. Participants were purposively selected based on their professional roles and extensive experience in healthcare facilities management. They included Facility Managers, Executive-Level Managers such as Head of FEMS, and Engineers. Ethical considerations were observed throughout the study, including informed consent and confidentiality measures to protect participants' identities. Data collection was carried out through in-depth, semi-structured interviews. This format allowed participants to express their experiences in detail while ensuring core areas were consistently addressed.

The interview data was analysed using content analysis. Responses were systematically transcribed, coded, and grouped to identify recurring patterns, themes, and key challenges. The thematic coding process involved both inductive and deductive approaches: initial codes were developed based on the literature and interview questions, and new themes were added as they emerged from the data. To ensure rigor, themes were validated through peer debriefing, iterative comparison, and cross-checking among researchers to minimize bias and confirm consistency.

This comprehensive qualitative methodology ensured the research instrument was grounded in both academic theory and practical insight, creating a dependable tool to investigate the challenges of facilities maintenance management and pathways to achieving operational efficiency in healthcare settings.

4.0 RESULTS AND DISCUSSION

The semi-structured interview methodology, which balanced conversational flexibility with a systematic approach, was used to explore the challenges and strategies related to facilities maintenance management in healthcare settings, aiming for efficient operation. The questionnaire was divided into two main sections. Section A focused on identifying the challenges of maintenance management that affect operational efficiency in healthcare settings. The questions in this section examined aspects such as strategic planning, scheduling, resource allocation, and the impact of unplanned maintenance tasks. Section B**,** on the other hand, aimed to gather suggestions and propose effective strategies for addressing and mitigating these challenges. This section used open-ended questions to capture participants' insights, recommendations, and practical solutions that could support improvements in operational efficiency and guide better maintenance management practices in the healthcare facilities

4.1 Variable 1: Strategic Planning and scheduling

Table 1: The Challenges of Strategic Planning and Scheduling in Facility Maintenance Management

Theme	Quotation
Structured Planning Varies by System Maturity	"We rely on a mix of digital tools and manual scheduling to structure preventive and corrective maintenance activities."
Unplanned Maintenance Disrupts Critical Operations	"Unexpected breakdowns delay services, strain technical teams, and directly reduce healthcare delivery efficiency."
Operational Disruptions and Resource Limitations Affect Schedule Compliance	"Unplanned repairs, limited manpower, and coordination issues with clinical operations often force us to delay scheduled maintenance."
Regulatory Standards Provide Structure and Prioritisation in Planning	"Compliance requirements guide our priorities and ensure critical systems are maintained within required timelines."

The interview data demonstrates that healthcare facilities struggle with structured planning systems, as evidenced by participants noting they "rely on a mix of digital tools and manual scheduling to structure preventive and corrective maintenance activities," which supports Lavy & Shohet (2021) assertion that complex scheduling systems often struggle with prioritising urgent maintenance tasks against routine preventive maintenance. The study's findings on unplanned maintenance disruptions, where participants reported that "unexpected breakdowns delay services, strain technical teams, and directly reduce healthcare delivery efficiency". The operational disruptions identified, including unplanned repairs, limited workforce, and coordination issues with clinical operations, often force us to delay scheduled maintenance, validate the theoretical understanding that ineffective work order management directly impacts healthcare service delivery quality, as highlighted by Madureira et al. (2023) regarding the importance of proper scheduling in optimising resource use and avoiding unnecessary delays in equipment repair or facility maintenance.

4.2 Variable 2: Resources and Budget Allocation

Table 2:The Challenges of Resources and Budget Allocation of Facility Maintenance Management

Theme	Quotation
Rigid Budget Limits Hinder Flexibility	"Our budgets are fixed annually and rarely account for unexpected costs or rising prices in materials and labour."

Allocation Prioritises Critical Assets, but the Total Budget is Inadequate	"While we prioritise life-critical systems, the overall budget often falls short of covering both preventive and corrective needs."
Preventive Maintenance Undervalued in Funding Decisions	"Securing funds is difficult because maintenance is still seen as a cost centre rather than a strategic investment."
Procurement Delays and Quality Compromises Due to Budget Gaps	"Budget limitations force us to delay procurement or settle for lower-quality parts, affecting long-term reliability."
Budget Constraints Result in Maintenance Backlogs	"Yes, we've had to postpone maintenance activities, which later caused bigger issues and more costly repairs."

The study found that allocating resources and budgets is a significant issue in facilities maintenance management, affecting the efficiency of healthcare facility operations. Healthcare facilities have limited budgets. The participants said, "Our budgets are fixed annually and rarely account for unexpected costs or rising prices in materials and labour". This validates Martinez and Lee (2022) findings that most healthcare organisations spend only 2-4% of their budget on maintenance, compared to the recommended 5-8%. "While we prioritise life-critical systems, the overall budget often falls short of covering both preventive and corrective needs". This supports the research indicating facility managers must choose between urgent repairs and long-term infrastructure expenditures due to budget restrictions. Purchase delays and quality compromises, such as "budget limitations force us to delay purchasing or settle for lower quality parts, affecting long-term reliability," support Knapik et al. (2024) claim that proactive maintenance spending can lower healthcare facility operational costs by 40% over ten years. This illustrates how short-term costs can lead to higher costs and maintenance backlogs, ultimately harming operational efficiency.

4.3 Variable 3: Technology Integration

Table 3: The Challenges of Technology Integration of Facility Maintenance Management

Theme	**Quotation**
Technology Adoption Varies Across Facilities	"Some facilities use advanced CMMS platforms, while others still rely on spreadsheets and basic scheduling tools."
Implementation Hindered by Cost and User Adaptability	"We face challenges like staff resistance, limited digital literacy, and integration costs when introducing new systems."

Lack of Integration Leads to Operational Inefficiencies	"Without proper integration, tracking, diagnostics, and timely maintenance becomes slow and disorganised."
Legacy Equipment Limits Efficiency and Automation	"Outdated systems prevent real-time monitoring and require manual intervention, delaying critical maintenance tasks."
Training Support Ranges from Structured Programs to Informal Learning	"Some companies offer certified workshops, while others rely on informal, on-the-job learning due to limited resources."

The findings indicate that managing healthcare facility maintenance is challenging due to the integration of technology. The research shows that some facilities utilise modern CMMS systems while others employ spreadsheets and basic office software, resulting in a technology divide that impacts maintenance efficiency. Lebea et al. (2024) noted that healthcare facilities face implementation challenges, including high initial investment costs, complex and outdated system integration, and cybersecurity issues. The study found that cost and user adaption issues restrict implementation, supporting Martinez and Lee (2022) claim that most healthcare organisations use reactive rather than proactive maintenance due to resource constraints. The lack of integration, tracking, diagnostics, and timely maintenance that causes operational inefficiencies supports Rakyta et al. (2024) conclusions that outdated CMMS systems lack real-time data and predictive maintenance. The research also highlights critical issues with outdated technology limitations, efficiency in technology training, and the need for informal, practical training due to limited resources, supporting Manchadi et al. (2020) findings that technological limitations significantly hinder healthcare maintenance operations. These findings show that technology integration involves a financial commitment, people training, and strategic implementation to overcome resistance and maximise operational benefits.

4.4 Variable 4: Personnel Skills

Table 4: The Challenges of Personnel Skills in Facility Maintenance Management

Theme	**Quotation**
Modern Technical and Digital Skills Are Lacking	"Our team struggles most with newer technology integration, diagnostics, and data-based maintenance systems."
Training Occurs Regularly but Is Often Limited in Depth	"Although we offer training sessions periodically, they're often general and don't go deep into emerging technical areas."
Talent Shortages and Retention Issues Due to Market Competition	"It's hard to find and keep skilled workers, especially with better offers from the private sector and urban facilities."

Skill Gaps Lead to Delays, Escalations, and Inefficiency	"When skills are lacking, maintenance tasks take longer or get outsourced, disrupting healthcare operations."
Ongoing Development Programs Aim to Bridge Gaps and Encourage Learning	"We invest in upskilling through internal workshops, certifications, and mentorship to keep our team sharp."

The results show that healthcare facilities' maintenance management teams struggle with integrating modern technical and digital skills, diagnostics, and data-based maintenance systems due to staff skills limitations. Training is regular but limited, failing to address emerging technical areas, which supports Mong et al. (2019) claim that healthcare maintenance requires unique combinations of technical expertise, regulatory knowledge, and adaptability. The study identified talent shortages and retention issues resulting from market competition, where skilled workers are drawn to better offers from the private sector and urban facilities. This aligns with Lebea et al. (2024), who found that psychological and adaptive skills are as necessary as technical skills. The skill gaps that cause delays, escalations, and operational inefficiencies support Lavy & Shohet (2021) claim that maintenance staff must possess comprehensive competencies to navigate complex healthcare environments. The research shows that internal workshops, certifications, and mentorship programs bridge gaps and encourage learning, demonstrating organisational recognition that addressing personnel skill challenges requires comprehensive training strategies beyond basic technical instruction to ensure efficient healthcare facility operations.

4.5 Variable 5: Communication and Coordination

Table 5: The Challenges of Communication and Coordination in Facility Maintenance Management

Theme	**Quotation**
Communication Practices Are Inconsistent Across Departments	"Although some tools are in place, communication is often informal or underutilised, leading to gaps in understanding."
Scheduling Conflicts and Role Misunderstandings Hinder Coordination	"Aligning maintenance with clinical operations is difficult, especially when staff don't fully understand the urgency of repairs."
Tracking Systems Vary Greatly in Efficiency and Structure	"Some use digital portals, while others rely on manual logs or chat groups, which can lead to delays and lost information."
Poor Communication Directly Impacts Service Delivery	"Delays, duplicate reports, and unclear responsibilities are common when communication breaks down."

Structured Communication Tools and Cross-Training Can Improve Collaboration	"Better coordination can be achieved through joint meetings, centralised platforms, and designated liaisons."

This research discovered that communication and coordination barriers in healthcare facility maintenance management considerably reduce operational efficiency. Interdepartmental communication issues, scheduling conflicts due to role misunderstandings, and different tracking systems align with Yousefli et al. (2019), who found that poor communication delays repair and puts patient safety at risk. The study's finding that informal communication often produces knowledge gaps supports Lavy & Shohet (2021) findings regarding the complex interdepartmental interactions in maintenance operations. Furthermore, the research confirms that organisations implementing structured communication tools and cross-training programs experience improved collaboration. These findings demonstrate that communication and coordination issues are not merely operational challenges but fundamental barriers to efficient healthcare facility management, requiring technological integration, standardised protocols, and enhanced interdepartmental collaboration to ensure patient safety and operational continuity.

4.6 Improvement

Table 6: The Strategies to Improve Efficient Operation in Healthcare Facilities

Theme	Quotation
Structured Scheduling and Digital Tools Drive Noticeable Improvements	"Digital tracking systems and structured preventive maintenance calendars have reduced downtime and improved task response."
Adoption of Smart Technologies and Automation is Key	"IoT, AI, and mobile tools can transform facility operations by predicting issues and streamlining workflow."
Skilled Workforce, Technology Funding, and Policy Alignment Are Needed	"We need better funding for technology upgrades, skilled staff, and management support to implement efficiency strategies fully."
Data-driven and Predictive Maintenance Will Define the Future	"The future is predictive as real-time dashboards, cloud integration, and AI will redefine healthcare facility management."

The research reveals that the maintenance management difficulties faced by healthcare facilities require a multifaceted solution that integrates technological advances, staff development, and systematic process improvements. The solutions of structured scheduling with digital tracking systems, innovative technologies such as IoT and AI, as well as skilled workforce development with adequate funding address the core challenges identified in this study. These ideas demonstrate that healthcare facilities must transition from reactive to proactive maintenance

through digital transformation and enhanced human resources. These strategies modernise healthcare facility maintenance through data-driven decision-making, real-time monitoring, and improved workforce competencies, creating a sustainable framework that can improve operational efficiency, reduce downtime, and ensure continuous patient care while optimising resource allocation and long-term facility performance.

5.0 CONCLUSION

In conclusion, addressing the challenges of facilities maintenance management is essential for ensuring efficient operations in healthcare settings. Emphasizing structured planning, transparent processes, and continual assessment allows for better prioritization of maintenance tasks, optimal resource allocation, and minimal disruption to critical healthcare services.

This research contributes to the field by offering a comprehensive understanding of the specific maintenance challenges that hinder operational efficiency in healthcare facilities. It highlights practical strategies such as adopting technology-driven maintenance systems, investing in personnel training, and aligning maintenance objectives with organizational goals to improve system reliability and patient care outcomes. These recommendations can help healthcare facility managers create safer, more responsive, and cost-effective maintenance environments.

The findings reveal that the challenges of facilities maintenance management have a significant impact on efficient operation at healthcare facilities, demonstrating significant challenges across five variables: strategic planning and scheduling, resource and budget allocation, technological integration, personnel skills, and communication and coordination. This research may contribute to suggesting effective strategies for addressing and mitigating all the challenges to improve operational efficiency at healthcare facilities.

Future research should explore the long-term effectiveness of implementing the proposed maintenance strategies across different healthcare facility types and sizes, including comparative studies between public and private healthcare institutions. A technology integration cost-benefit analysis, as well as the impact of emerging technologies such as artificial intelligence and machine learning on predictive maintenance, may also provide valuable insights. Further research into maintenance management efficiency and patient satisfaction scores, as well as sustainable maintenance practices and their environmental impact on healthcare facilities, would enhance facility management approaches and aid in developing stronger healthcare maintenance frameworks.

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The Effectiveness of Maintenance Management Practice in Commercial Buildings

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ABSTRACT

This study investigates the effectiveness of maintenance management practices in commercial buildings by identifying the key factors that influence operational performance. The main objective is to propose strategies for improving maintenance operations by addressing common challenges such as budget constraints, insufficient staff training, and low levels of technology adoption. A qualitative research approach was employed using semi-structured interviews with facility managers, engineers, and maintenance technicians from three selected buildings: Pertama Complex, Wisma TNB Kepong, and Pos Malaysia. Thematic analysis revealed five core themes: implementation of preventive and corrective maintenance, management of tenant complaints, financial limitations, workforce competency, and the use of technology in maintenance activities. Findings indicate that although preventive maintenance is recognized as essential, many organizations remain reliant on reactive approaches due to financial limitations and a lack of training. Technological tools such as Computerized Maintenance Management Systems (CMMS) and Building Management Systems (BMS) have proven to enhance efficiency, yet their usage is often limited by cost factors and resistance to new systems, especially among older staff. Skill gaps among maintenance personnel also contribute to delays and reduced work quality. Therefore, improving maintenance effectiveness requires a holistic approach involving adequate funding, continuous staff development, and the integration of modern digital tools. Such improvements are crucial for ensuring sustainable, efficient, and reliable building maintenance operations.

Keywords: maintenance management, commercial building, facility management, building performance, maintenance strategy

1.0 INTRODUCTION

1.1 Research Background

For commercial buildings to remain functional, comfortable, and sustainable, maintenance management is essential. Maintenance management is crucial for sustaining building value and operating efficiency. They are defined as a collection of technical and administrative operations designed to maintain or restore an asset to a state in which it can fulfil its intended purpose (Sylvia, 2019). Maintenance makes ensuring that commercial buildings which include offices, shops, hotels, and industrial facilities support company activities in a safe and efficient manner (Yudelson, 2020).

Effective maintenance procedures are difficult to adopt in many commercial buildings, despite their significance. A significant issue that impedes effective operation and monitoring is the absence of cutting-edge technology like Computerized Maintenance Management Systems (CMMS) and Building Management Systems (BMS) (Ali et al., 2019). Furthermore, inefficiencies and higher repair costs result from maintenance workers' lack of training and skill development (Smith, 2020). These problems are made worse by financial limitations and the deterioration of structures, which affects the facility's lifetime and overall performance.

1.2 Problem Statement

Commercial buildings often face challenges in maintaining their infrastructure efficiently. The absence of cutting-edge technology like BMS and CMMS, inadequate maintenance personnel training, and constrained funding are some of the key problems. These difficulties lead to decreased tenant satisfaction, increased operating expenses, and frequent equipment breakdowns. Additionally, maintaining older buildings takes more money and trained labor, which puts a burden on available resources and affects service delivery.

1.3 Research Aim

The aim of this study is to provide effective strategies to improve maintenance management practices in commercial buildings.

1.4 Research Objective

- To identify the factors that influence the effectiveness of maintenance management practices in commercial buildings.
- To analyze the factors that influence the effectiveness of maintenance management practices in commercial buildings.
- To propose strategies to improve maintenance practices in commercial buildings.

1.5 Scope of Study

This research focuses on maintenance management practices within three commercial buildings: Pertama Complex, Wisma TNB Kepong, and Pos Malaysia. The study targets participants directly involved in building maintenance, including facility managers, engineers, and technicians. It is limited to qualitative data collected through one-on-one, semi-structured interviews.

2.0 LITERATURE REVIEW

2.1 Maintenance Management

Implementing maintenance management methods is crucial for guaranteeing the longevity and efficiency of structures. Both the facility's inhabitants and maintenance operations may suffer as a result of poor maintenance management. If routine maintenance is not performed, buildings may deteriorate more quickly and lose some of their functioning. Inadequate maintenance practices can impair building occupant productivity and create a disruptive environment that makes teaching and learning more difficult. (Myeda and others, 2018)

2.2 Effectiveness of Maintenance Management Practice

Maintenance management plays a pivotal role in ensuring optimal functioning, safety, and overall performance of commercial buildings. According to Cobbinah and Hons (2010), effective maintenance techniques are essential to address the challenges faced by these buildings, which have increasingly become focal points in recent studies due to both the opportunities they present and the issues they encounter.

Commercial buildings, serving diverse functions from offices to retail spaces, require meticulous upkeep to sustain their operational efficiency and ensure occupant safety. Maintenance management encompasses a range of activities, including preventive maintenance to forestall breakdowns, corrective maintenance to address immediate issues, and predictive maintenance leveraging technology to anticipate potential failures.

Moreover, effective maintenance practices contribute significantly to the longevity of building systems and infrastructure, thereby protecting the considerable investments made in their construction and ongoing operation. This proactive approach not only minimizes disruptions but also enhances the overall user experience, promoting a conducive environment for tenants and visitors alike.

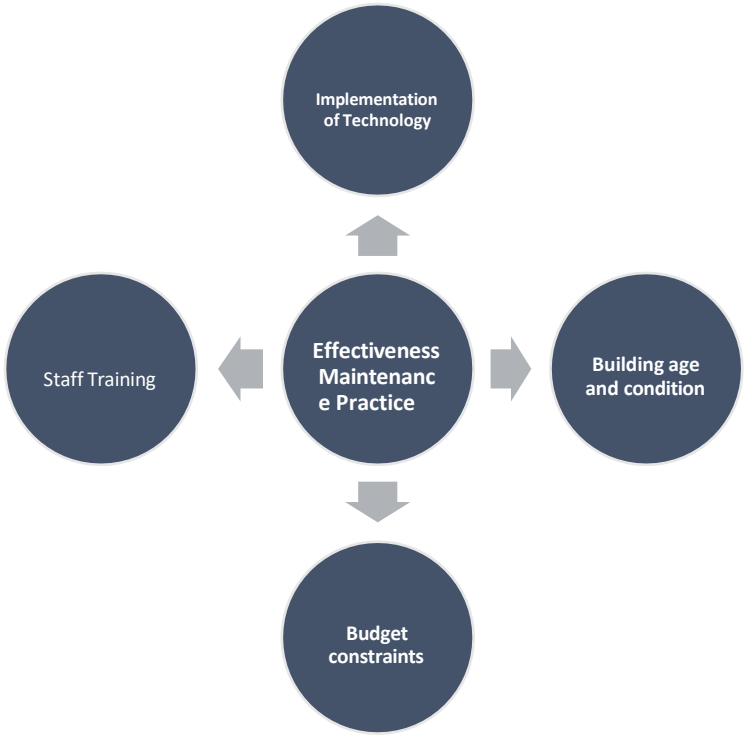

Diagram 1 : Effectiveness of Maintenance Practice

2.3 Implementation of Technology

The integration of technology into maintenance practices has become a key factor in enhancing the operational efficiency and functionality of commercial buildings. West et al. (2024) emphasize the benefits of using systems such as Building Management Systems (BMS) and Computerized Maintenance Management Systems (CMMS), which have significantly modernized maintenance operations. These technologies allow facility managers to automate routine tasks, monitor building systems in real time, and make informed decisions based on accurate data. By streamlining processes such as work order tracking, asset management, and maintenance scheduling, these tools help reduce equipment downtime and extend the life of building systems. Additionally, they support energy efficiency efforts by optimizing system performance and reducing unnecessary energy consumption. Overall, the adoption of BMS and CMMS contributes to more proactive, cost-effective, and sustainable maintenance practices, aligning with the evolving needs of today's commercial buildings.

2.4 Building Age and Condition

The age and physical condition of a building play a significant role in determining the type and intensity of maintenance required. According to Dzulkifli et al. (2021), older buildings tend to present more complex maintenance challenges due to the natural deterioration of structural components over time. These aging infrastructures often require frequent repairs, system upgrades, and retrofitting to meet modern standards, which leads to higher maintenance costs and increased resource demands. Additionally, integrating energy-efficient technologies into

older buildings can be difficult, as it may involve significant modifications to outdated systems. As a result, managing such buildings effectively requires well-structured long-term maintenance planning and consistent inspections to identify issues early and prevent further degradation. These strategies are essential to ensure that older facilities remain functional, safe, and aligned with current performance expectations.

2.5 Budget Constrains

Budget constraints significantly affect the effectiveness of maintenance operations and the overall performance of commercial buildings. Kong (2021) highlights that limited funding often results in reduced maintenance efforts, which can lead to higher repair costs and compromised building functionality. When financial resources are tight, essential maintenance tasks may be delayed or overlooked, increasing the risk of equipment failure and unplanned emergency repairs. This not only disrupts building operations but also leads to a cycle where neglecting routine maintenance causes more severe and expensive issues in the future. To break this cycle, it is crucial to allocate resources wisely and develop strategic maintenance plans that address immediate needs while also considering long-term performance goals. Effective budgeting and planning can help ensure the sustainability and reliability of building systems despite financial limitations.

2.6 Staff Training

Staff training plays a crucial role in ensuring the effectiveness of maintenance practices in commercial buildings. Effective repair work, early detection of any problems, and fast maintenance job execution all depend on having properly trained staff. The quality of maintenance services may be considerably raised by training programs that emphasize both technical proficiency and the use of maintenance management systems, according to research. According to a research, continuous staff training guarantees that the team has the skills necessary to manage new technologies and procedures and assists building managers in keeping up with the changing requirements of building systems (Tan, 2021).

3.0 METHODOLOGY

This study investigates the efficacy of maintenance management procedures in commercial buildings using a qualitative research technique. A thorough grasp of the experiences, viewpoints, and difficulties encountered by professionals engaged in maintenance operations is made possible by the qualitative method. Since it is in line with comprehending the participants' subjective experiences and points of view, the interpretivist research philosophy was chosen.

3.1 Research Design

In this study, an inductive research methodology was applied. The objective was to draw conclusions and find themes from the gathered data rather than test a hypothesis. This method works well for exploratory research, particularly when looking at practical topics like maintenance management procedures.

3.2 Research Instrument

A semi-structured interview was the main tool used to obtain data. While keeping a uniform framework throughout the interviews, this method allowed us flexibility in delving further into the participants' comments. The interview questions were created to address a range of maintenance management topics, such as building age, staff training, budget allocation, and technology use.

3.3 Sampling and Participant

Purposive sampling was used to select participants who are directly involved in building maintenance operations. Ten professionals from three business buildings Pertama Complex, Wisma TNB Kepong, and Pos Malaysia participated in the study. Four maintenance workers, three engineers, and three facilities managers were among the attendees. These people were chosen because of their positions and background in overseeing or carrying out maintenance duties.

3.4 Data analysis

Thematic analysis was used to identify, analyze, and report patterns within the interview data. The researcher was able to record recurrent themes on the efficacy of maintenance management procedures by using this approach. Coding the data, finding themes, and interpreting the findings in light of the study's goals were all steps in the analytic process.

4.0 RESULTS AND DISCUSSION

This section highlights the primary findings obtained from interviews with maintenance personnel and facility managers at three commercial buildings. Through thematic analysis, five key themes were identified: preventive and corrective maintenance, tenant complaint management, financial limitations, workforce skill levels, and the role of technology in maintenance activities. These themes shed light on current practices and challenges in maintenance management, providing insights into areas that require improvement..

4.1 Preventive and Corrective Maintenance

Preventive maintenance was acknowledged by participants as an essential strategy for minimizing system failures and extending the lifespan of building equipment. However, despite its recognized importance, many respondents indicated that financial and resource limitations often hindered the ability to consistently perform preventive maintenance tasks. As a result, corrective maintenance, which is more reactive and typically involves higher costs, was more commonly practiced. This finding is consistent with existing research by Sylvia (2019), which observed that while preventive maintenance is critical, organizations often default to reactive strategies due to budgetary constraints. Similar studies by Cobbinah & Hons (2010) and Dzulkifli et al. (2021) also highlighted that the financial challenges faced by maintenance teams often lead to increased reliance on reactive maintenance, despite its long term cost implications.

4.2 Tenant Complaint Handling

Effectively managing tenant complaints was another theme that emerged strongly. Respondents emphasized that timely and efficient resolution of complaints is vital to maintaining tenant satisfaction and preventing recurring issues. However, delays in addressing these concerns were often caused by a lack of manpower and slow internal processes. This issue mirrors findings in Myeda et al. (2018), who pointed out that poor maintenance management often leads to tenant dissatisfaction and operational inefficiency. Interviewees suggested that improvements in communication protocols and a more systematic approach to complaint handling could significantly enhance tenant relations and service quality. These insights highlight the need for an organized complaint management system that ensures a swift response to tenant concerns, improving both satisfaction and operational performance.

4.3 Financial Constraints

Budgetary limitations were frequently cited as a significant barrier to effective maintenance management. Many respondents shared that their available maintenance budgets were insufficient to meet the needs of both preventive maintenance and technology upgrades. Consequently, this financial pressure often resulted in delayed maintenance actions, which increased the likelihood of more severe and costly repairs in the future. This aligns with Kong (2021), who identified limited financial resources as a primary obstacle to the proactive maintenance of commercial buildings. Effective allocation of funds, along with better financial planning, was seen as essential to overcoming these constraints. Future strategies should focus on balancing short-term needs with long-term sustainability to ensure more effective and consistent maintenance operations.

4.4 Workforce Capability

The skills and training of maintenance staff were critical factors in determining the effectiveness of maintenance management. Many respondents expressed concern over the insufficient training of staff, which led to inconsistent work quality and a dependency on external contractors. This observation supports findings by Tan (2021), who highlighted that continuous training is necessary to keep maintenance teams updated on emerging technologies and industry best practices. The study revealed that investing in staff development through technical certifications and specialized training programs is crucial for improving performance and reducing reliance on third-party service providers. Upskilling maintenance personnel should be prioritized to enhance their ability to manage modern maintenance requirements and technologies effectively.

4.5 Technology Utilization

The integration of technology into maintenance operations was recognized as a key factor for improving efficiency. However, the uptake of technologies like Computerized Maintenance Management Systems (CMMS) was limited by budget constraints and staff resistance, especially among older employees. As highlighted by West et al. (2024), tools such as CMMS and Building Management Systems (BMS) can significantly enhance the efficiency of maintenance practices by automating routine tasks, improving asset tracking, and enabling data-driven decision-making. Despite these benefits, financial limitations and the reluctance to adopt new technologies remained obstacles. Participants suggested that investing in gradual training and demonstrating the long-term benefits of these systems would help overcome resistance and enhance their overall maintenance strategies.

5.0 CONCLUSION

This study confirms that while maintenance teams recognize the importance of preventive maintenance and the potential of technological tools, practical challenges such as budget constraints, insufficient training, and resistance to technological adoption hinder their consistent application. These findings align with previous research by Ali et al. (2019) and Sylvia (2019), which emphasized that financial and resource limitations often lead to reactive maintenance practices. The study also reinforces the critical role of technology in streamlining maintenance processes, as discussed by West et al. (2024).

To overcome these barriers, organizations must focus on improving financial planning, investing in staff development, and gradually adopting modern technologies. By addressing these challenges, maintenance operations can become more proactive and integrated, contributing to better building performance and long-term cost savings.

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The Efficiency of E-Waste Management Strategies Towards The Sustainability Environment In Office Building

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ABSTRACT

This study investigates the ways in which office buildings' current e-waste management procedures can encourage environmentally friendly work practices. The study evaluates the efficacy of current tactics and suggests enhancements, with a focus on three organizations: Pos Malaysia headquarters, Ampang Jaya Municipal Council (MPAJ), and Klang Valley Malaysian Communications and Multimedia Commission (MCMC). These locations were chosen based on their use of electronic equipment and administrative functions. Direct observations, interviews with facility managers and environmental officers, and examination of records including sustainability reports and e-waste disposal logs were used to collect data using a qualitative methodology. According to a summative content analysis, there are notable gaps in policy enforcement, staff understanding, and cooperation with certified recyclers, even though certain sustainability objectives and laws are followed. These flaws endanger human and environmental health and impede the shift to a circular economy. The study comes to the conclusion that while the fundamentals of managing e-waste are in place, their efficacy is compromised by uneven application, low employee involvement, and inadequate supervision. Sustainable office practices require increased knowledge, more robust regulation.

Keywords: e-waste, sustainability, management, strategy, efficiency

1.0 INTRODUCTION

1.1 Research Background

Rapid advances in technology and rising electronic consumption have made e-waste a major global problem. In 2019, 53.6 million metric tonnes of e-waste were generated worldwide, yet only 17.4% of that amount was formally recycled (Forti et al., 2020). There are major threats to the environment and human health when hazardous compounds like heavy metals are found in e-waste. The issue is made worse by the fact that underdeveloped countries mostly rely on unofficial means of recycling, whereas wealthier nations have established infrastructures for this purpose (Duangthong & Boonmee, 2022). According to Romel et al. (2022), technological advancements such as hydrometallurgical and pyrometallurgical processes provide potential recycling options, while frameworks like the EU's WEEE Directive and Extended Producer Responsibility (EPR) are important policy models (Balaz, 2021). Systemic inefficiencies, lax enforcement of regulations, and ignorance persist in many areas, nevertheless. By examining the present e-waste management practices in a few chosen office buildings, this study attempts to assess their efficacy and suggest changes for more sustainable and ethical electronic waste management.

1.2 Aim & Research Objective

The goal of this study is to improve sustainability in building settings by suggesting an innovative approach to e-waste management. The objectives have been developed to achieve the objective of the study and answer the research question: The objectives have been developed to achieve the objective of the study and answer the research question:

i. To identify the existing e-waste management strategy in building.
ii. To analyze the effectiveness of existing strategy in e-waste management.
iii. To suggest best practices of e waste management system in organization.

The study aims to accomplish this by identifying the e-waste management solutions now in use in buildings, evaluating their efficacy, and proposing best practices for enhancing organisational e-waste management systems. How to improve the efficiency of e-waste management systems in office buildings ?, how awareness ?, infrastructure ?, and regulations affect their efficacy ?, and what sustainable practices can be implemented to improve e-waste handling in building projects are the main questions that drive the research?. The overall purpose of encouraging a more sustainable environment through creative and effective e-waste management solutions is intended to be addressed by these goals and enquiries.

2.0 LITERATURE REVIEW

E-waste is one of the fastest-growing global waste streams, making effective management strategies essential for environmental sustainability. Efficient recycling systems can recover valuable materials and reduce landfill use, as highlighted by studies such as (Kumar et al., 2023) which emphasize economic viability and advanced separation technologies. Policy frameworks like the EU's WEEE Directive have set global standards by enforcing producer responsibility, although implementation in developing countries remains challenging due to weak infrastructure and enforcement (Kiddee et al., 2013). Consumer awareness and participation are also vital, with public education and incentive programs helping to reduce improper disposal and increase engagement (Balde et al., 2017). However, ongoing issues such as informal recycling practices, limited public involvement, and financial and infrastructure gaps continue to hinder the overall success of e-waste management systems and their contribution to sustainable environmental practices.(Romel et al., 2022)

2.1 The Efficiency Of E Waste Management Strategies Towards The Sustainability Environment.

E-waste, or electronic waste, represents one of the fastest-growing waste streams globally. With the increasing proliferation of electronic devices, effective management of e-waste is crucial for achieving environmental sustainability.(Dhillon & Sandhu, 2017) This literature review examines the efficiency of various e-waste management strategies and their contribution to sustainable environmental practices. Key areas of focus include recycling, reusing, policy frameworks, innovative technologies, and consumer awareness and participation.(Awasthi et al., 2021)

2.2 Recycling system

Recycling is one of the most common methods for managing e-waste. Studies have shown that efficient recycling processes can significantly reduce the environmental impact of e-waste by recovering valuable materials and minimizing landfill use. For instance, Cucchiella et al. (2015) highlight the economic viability of recycling rare earth elements from discarded electronics,

which reduces the need for virgin material extraction. Similarly, (Kumar et al., 2023). emphasize the role of advanced separation technologies in improving recycling efficiency, particularly in segregating plastics, metals, and hazardous components.(Nizetic et al., 2019) This component focuses on developing and optimizing efficient recycling processes for electronic waste. It includes the establishment of proper collection, sorting, and processing systems that can handle various types of e-waste, ensuring that materials are recovered and reused rather than ending up in landfills. The framework emphasizes the integration of advanced recycling technologies and efficient logistics to ensure that e-waste is managed responsibly and in an environmentally friendly manner.

2.3 Policy and regulatory

Effective policy frameworks are critical to the success of e-waste management strategies. The European Union's Waste Electrical and Electronic Equipment (WEEE) Directive serves as a benchmark, enforcing producer responsibility and ensuring proper e-waste collection and recycling (O. & D., 2011). On the other hand, developing countries often face challenges in implementing such policies due to inadequate infrastructure and enforcement mechanisms (Kiddee et al., 2013).This component deals with the creation and enforcement of policies and regulations that support sustainable e-waste management. It includes government laws, industry standards, and building-specific policies that regulate the disposal and recycling of electronic waste. Strong regulatory frameworks are essential for ensuring that office buildings comply with environmental guidelines, incentivizing sustainable practices, and holding stakeholders accountable for proper e-waste handling.

2.4 Awareness participation

Consumer awareness and participation play a pivotal role in the success of e-waste management strategies. Effective disposal and recycling depend significantly on public understanding of e waste's environmental impact. Campaigns to educate consumer about proper e-waste disposal practices can enhance participation rates. For example, (Baldé et al., 2017) .emphasize that lack of consumer engagement often leads to improper disposal, exacerbating environmental hazards. Incentive programs and community-based initiatives have also proven effective in encouraging individuals and businesses to participate actively in recycling and reuse programs. This component highlights the importance of engaging office building occupants and other stakeholders through education and awareness campaigns. By raising awareness about the environmental impacts of improper e-waste disposal and the benefits of recycling, this framework aims to encourage active participation from employees, management, and vendors. It also involves training programs and communication strategies to promote better understanding and involvement in e-waste management initiatives.

2.5 Sustainable practices

Despite these advancements, several challenges persist. Informal e-waste recycling in developing countries often leads to significant environmental and health risks due to the release of toxic substances. Additionally, the lack of consumer awareness and participation in e-waste disposal programs hinders the effectiveness of these strategies (Balde et al., 2017) . Infrastructure gaps and financial constraints further complicate the implementation of efficient e-waste management systems. This component encompasses a range of practices aimed at minimizing the environmental footprint of e-waste. It includes not only recycling but also the promotion of practices like reusing electronics, extending the lifespan of devices through repair

and maintenance, and adopting greener alternatives such as energy-efficient electronics. The focus is on embedding sustainability into the culture of the office building by encouraging responsible consumption and fostering an environmentally conscious approach to technology use and disposal.

2.6 CONCEPTUAL FRAMEWORK

There are four (4) constructs are formed in this research framework. The research framework is as figure below:

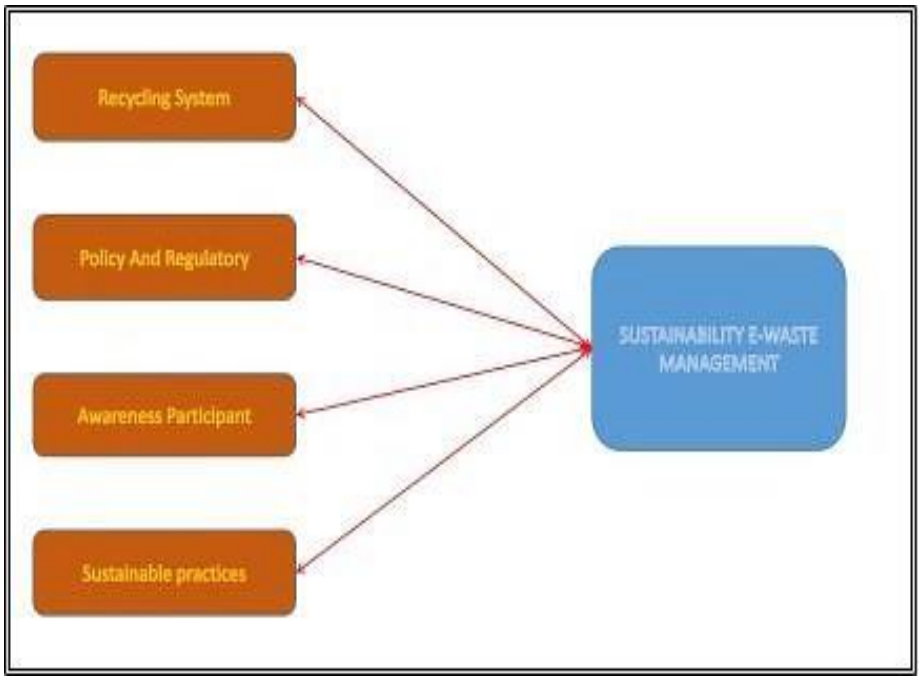

Figure 1 Conceptual Framework of The Efficiency of E-Waste Management Strategies Towards the Sustainability Environment In Office

3.0 METHODOLOGY

This research involves data collection using qualitative methods to gain a comprehensive understanding of e-waste management strategies within selected buildings. Data will be gathered through semi-structured interviews with key personnel such as Safety Officers, Facilities Managers, and Building Executives to explore the practical implementation and outcomes of existing e-waste strategies. Additionally, on-site observations will be conducted to assess how employees and management engage with e-waste handling procedures, identifying any operational inefficiencies. Document analysis of relevant materials such as energy audit reports and internal strategy evaluations will further support the data gathered. The proposed buildings for this study around Klang Valley include MCMC in Cyberjaya, MPAJ, Hulu Langat, and Pos Malaysia HQ. To interpret the collected data, a summative content analysis will be employed, allowing for the identification of recurring themes, patterns, and gaps, ultimately contributing to the formulation of improved e-waste management practices.

3.1 Research Approach (Qualitative method)

Semi-Structured Interviews approach; the researcher conducts interviews with key stakeholders such as Safety Officers, Building Executives, Facility Managers, and Green Executives. These individuals are typically involved in the operational, regulatory, and environmental aspects of managing office buildings. The semi-structured format allows for a flexible conversation where the researcher can explore specific topics of interest related to e-waste management, while also leaving room for participants to share their experiences, opinions, and insights. This method enables the researcher to understand how these professionals perceive the challenges and opportunities of implementing sustainable e-waste practices in office environments. The interviews will focus on topics like existing e-waste management systems, policies, barriers to sustainability, and recommendations for improving practices in the context of office buildings.

3.2 Document Analysis

This method involves analyzing relevant documents, including acts, regulations, and reports related to e-waste management, sustainability, and environmental policies. By reviewing government regulations, industry standards, and internal building management reports, the researcher can gain a comprehensive understanding of the legal and policy frameworks that guide e-waste disposal and recycling in office settings. Document analysis helps identify gaps in existing legislation, regulations, and building-specific policies that could hinder or support sustainable e-waste management. It also helps the researcher understand how well these guidelines are being implemented and what improvements are needed to align them with sustainability goals.

3.3 Safety Officer

The Safety Officer plays a critical role in ensuring that the building and its operations comply with safety regulations, including environmental safety related to e-waste disposal and handling. Their expertise in workplace safety and their knowledge of applicable health and safety standards can significantly contribute to the validity of the research. Safety Officers can offer insights into the specific safety risks associated with e-waste, such as the handling of toxic materials or the prevention of accidents during disposal or recycling processes. By interviewing the Safety Officer, the researcher can ensure that the e-waste management practices being examined are not only legally compliant but also focused on safeguarding both people and the environment. The Supervisor of Facility Management and Operations (FMP) lecturer supervisor plays a key role in overseeing the academic aspects of facility management, particularly in the integration of practical knowledge with theoretical learning. Their perspective provides valuable insights into the research, as they have a deep understanding of current e-waste management systems and how they relate to both academic and practical applications in the field.

3.4 Research Design

Figure 2 Research Design of The Efficiency of E-Waste Management Strategies Towards the Sustainability Environment In Office Building.

4.0 RESULT AND DISCCUSION

The results of interviews with facility managers, QSHE department staff, and building executives at three locations MPAJ Hulu Langat, MCMC Cyberjaya, and Pos Laju Malaysia Headquarters are presented and discussed in this chapter. Four major topics emerged from the data analysis, which was conducted using thematic coding. Background and General Understanding, Current Strategies and Practices, Difficulties and Limitations, and Effectiveness and Suggestions for Improvement.

4.1 Background and General Understanding

Although the breadth and depth of their knowledge differed, participants from all three sites showed a basic comprehension of e-waste management. Data security during disposal and regulatory compliance were prioritized at Pos Laju Malaysia HQ. Facility managers worked with suppliers and IT to organise disposal logistics, pointing out problems including storage restrictions and collection delays. With an emphasis on secure disposal methods and sustainability leadership, MCMC Cyberjaya demonstrated a more methodical approach. There, stakeholders noted issues with logistics of handling and storage as well as planned management of e-waste. Compliance with municipal policies and personnel awareness were clearly prioritized in MPAJ Hulu Langat. Operational problems, such sluggish approval procedures and inadequate storage, remained persistent, nevertheless. These observations show different levels of e-waste comprehension maturity, with MCMC Cyberjaya setting the standard for organized procedures and consciousness.

4.2 Existing Strategies and Practices

Internal protocols that are in line with DOE or local laws are used at all three locations. Standard Operating Procedures (SOP), which prioritized secure handling and vendor interaction, were

frequently cited, particularly at Pos Laju and MCMC. E-waste is handled in a safe, access controlled location at Pos Laju, and resale is not allowed because of data concerns. Items are tracked until vendor collection by manual documenting and digital labelling. To further improve compliance, MCMC requires verified data wiping and adheres to quarterly scheduled collections. Accountability and tracking are streamlined via a digital asset system and handover forms. Working together with Alam Flora and authorized recycles is crucial to MPAJ. Inconsistency is introduced by the system's reliance on departmental reporting and manual techniques. Although all sites have plans in place, MCMC uses more reliable digital systems than the others, and there are differences in the level of integration and technology adoption.

4.3 Challenges and Constraints

Storage Restrictions, every site mentioned having insufficient or badly planned storage space, particularly when dealing with disposal permission delays. Budgetary Restrictions, Participants from Pos Laju and MCMC mentioned budgetary constraints, citing departmental budgets being strained by the costs of certified vendors. Understanding Gaps, Inadequate understanding among general employees and contractors frequently resulted in inappropriate disposal methods, especially at Pos Laju and MPAJ. Policy and Process misunderstanding, At MPAJ, varying comprehension of disposal procedures led to departmental misunderstanding and delays in procedures. Problems with Manpower, MCMC observed that a lack of employees affected supervision, particularly during periods of high disposal. These difficulties point to a structural requirement for better infrastructure investment, employee training, and more transparent communication.

4.4 Effectiveness and Suggestions for Improvement

On a scale of 1 to 5, participants evaluated how successful their e-waste management procedures were; the overall findings showed that all three organization methods were moderately effective. Because of its frequent vendor pickups and organized standard operating procedures, MCMC obtained the highest ratings mostly 4s though manual reporting was still a notable drawback. Pos Laju had an average grade of 3, indicating that although regulatory compliance was mostly met, personnel awareness and disposal process efficiency needed to be improved. With evaluations ranging from 2 to 3, MPAJ received a somewhat lower score, indicating uneven implementation and staff misunderstanding of appropriate e-waste disposal protocols. Participants suggested a number of changes to increase efficacy, such as centralising funding for e-waste management, implementing focused employee training initiatives and awareness campaigns, digitising asset tracking and reporting systems, and expediting approval procedures to reduce wait times.

5.0 CONCLUSION

The purpose of this study was to identify current practices, evaluate their efficacy, and recommend improvements towards environmental sustainability by evaluating the effectiveness of e-waste management strategies in three specific office buildings: MCMC Cyberjaya, MPAJ Hulu Langat, and Pos Laju Malaysia HQ. Although all three organizations have set up fundamental frameworks for handling e-waste, the results showed that these frameworks' efficacy varied greatly because of variations in infrastructure, personnel participation, and execution. Even if issues like manual reporting and a shortage of staff still exist, MCMC Cyberjaya showed the most organized and reliable procedures, backed by planned vendor

pickups and digital asset management. While MPAJ Hulu Langat encountered the most significant challenges, notably in communication, policy enforcement, and staff knowledge, Pos Laju Malaysia HQ complied with regulatory standards but had gaps in staff awareness and process efficiency. Across all sites, recurring issues including poor knowledge, tight funds, and inadequate storage were found to be significant barriers. The report suggests centralizing e-waste budget allocation, improving employee awareness and training, digitizing asset monitoring, and streamlining administrative processes to reduce delays in order to solve these problems. In the end, a more proactive and comprehensive strategy is required for e-waste management to significantly contribute to sustainability goals in office settings. This strategy should include clear policy direction, technical assistance, and regular stakeholder interaction.

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The Factors that Influence Senior Employees Motivation towards Job Performance within Facilities Management Companies

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ABSTRACT

Employee motivation is critical to organisational success. However, many companies struggle to keep their experienced employees engaged and performing well. This study looks into ways to improve motivation and job performance in senior employees in the facility management sector. This study employs qualitative research methods. The qualitative data collected from semi-structured interviews with 9 senior facility personnel from three different locations of an organization provide valuable insights into the incentive factors that have the greatest impact on this particular group. An inductive analysis shows that compensation, co-worker bonds, autonomy, and a supportive culture all have a consistent positive impact on engagement. Participants' top priorities are work culture, co-worker relationships, salary, and job autonomy. The findings provide a framework for leaders who want to improve the performance of their senior employees by implementing tailored recognition programs, empowering initiatives, and engagement strategies that draw on both external and internal motivations. Practical insights give executives the tools they need to rejuvenate their highly skilled managers while encouraging consistency, mentorship, and career advancement. This study improves understanding of strategies for maintaining the performance of experienced employees, which is critical for success in facility management.

Keywords: motivation, performance, facilities, management, employees.

1.0 INTRODUCTION

Organisations are increasingly focussing on creating "best places to work" and improving employee well-being. Research suggests that organisations with happy employees experience numerous economic and non-economic benefits, such as lower absenteeism, turnover, productivity, and financial performance. (Arampatzi & Burger, 2020)

1.1 Research Background

Robbinson et al. (2007) and Basu (2023) emphasise the significance of comprehending employee motivation factors. Leaders should explore the factors that truly motivate employees, rather than just asking if they are motivated. Performance is influenced more by intrinsic passions than external factors. Companies need strategies to engage and energise their workforce, despite motivation being less important than its source. Leaders should foster motivation and personalised conditions for each team member.

Additionally, the workforce provides the vitality and core of any organisation. Organisational success depends on employee performance. Enhanced employee performance can significantly impact outcomes, even with minor changes. Performance of the organisation. Critical steps are needed to achieve the company's goals. Mohamad Shammout (2022) discovered that the work environment affects employees' behaviour, indicating its effectiveness and efficiency.

Tanjung and Wahdiniwaty (2020) found that employee sentiment affects performance. Dissatisfied teams produce lower quality and output, while happy staff members have higher productivity. Feelings and job satisfaction drive workplace effort and excellence. Creating positive and supportive cultures can lead to peak performance, while negative environments can hinder results. Monitoring and responding to employee perspectives is crucial.

Integrated strategies addressing employee satisfaction, change management, and motivation are crucial for organisations. Facilities management companies must optimise these three interconnected aspects of the workplace in the modern workplace. Successful organisations rely on the ability to motivate individuals, navigate sectoral transitions, and support staff. To ensure peak performance, leaders must balance worker psychology, cultural adaptation, and personal passions.

Modern businesses operate in a complex environment that integrates technology and human dynamics. Successful leaders of companies address both tangible and intangible factors to maintain a competitive advantage. Maintaining a balance between hard elements like materials and processes and soft dimensions like motivation and culture is crucial.

1.2 Problem Statement

Basu (2023) noted that worker disengagement and motivation are growing issues. Lost interest in work or the company causes poor performance and failure. Without passion, people work mediocrely. Restoring engagement and intrinsic motivation is essential for organisational success.

An employee who feels like a misfit at work may still be qualified. A study found that workplace stress and inadequacy can hurt employee performance. For instance, if he is given too much work and not enough time or support. He may be rewarded for reaching those goals. His dissatisfaction may lead to job stress and a lack of supervisor support. Unsatisfactory work environments can negatively impact employee performance and cause psychological issues such as demotivation and restlessness, ultimately impacting organisational success. (Mohamad Shammout,2022).

Tanjung and Wahdiniwaty (2020) found that job satisfaction significantly affects employee performance. Unhappy employees are less productive and more likely to quit, while happy employees work harder and are more loyal to their employer. Workplace impact boosts effort and retention. Creating positive cultures is crucial for facilities management companies to achieve maximum success.

In summary, modern businesses must balance tangible outcomes like budget and schedule with human dimensions like satisfaction and satisfaction rate. Company leaders can maintain their advantage by combining hard and soft metrics. It is beneficial for FM companies to prioritise workforce psychology over capital assets alone.

1.3 Aim

To propose strategies to enhance motivation among senior employees in facility company.

1.4 Research Objectives

i. To determine factors, motivate senior facility management company employees.

ii. To analyse which most factor motivate senior facility management company employees.
iii. To enhance senior employees of facility company performance.

2.0 LITERATURE REVIEW

2.1 Salary

Salary continues to be one of the most critical factors in the motivation and retention of employees. Ntambu and Loang (2022) underscore the importance of pay remuneration in the context of employee retention and motivation, particularly in industries that are highly competitive. Their research emphasises the necessity of conducting more complete studies on the impact of pay compensation on worker performance, particularly in specific regional contexts like China. This discovery emphasises the significance of competitive compensation packages in preserving the motivation and stability of the workforce in a variety of market environments.

2.2 Co-worker relationship

Employee motivation and job satisfaction are substantially determined by the quality of workplace relationships. Sloan (2011) illustrates that the establishment of a more favourable work environment is contingent upon the support of supervisors and colleagues, which results in more engaged employees, increased job satisfaction, and an enhanced work-life balance. McAllister (2015) expands upon this concept by offering a more profound understanding of the psychological mechanisms at work. He explains that the support of colleagues and superiors can enhance psychological conditions, including psychological safety, availability, and meaning, thereby increasing employee engagement. McAllister also observes that supportive relationships facilitate the development of a sense of psychological safety, trust, purpose, and belonging within the workplace.

2.3 Job autonomy

In the context of technological advancement and organisational structure, job autonomy has emerged as a critical motivational factor. Alavi et al. (2016) note that the introduction of new technologies has significantly altered traditional work arrangements by granting workers more autonomy. Nevertheless, autonomy remains restricted in numerous organisations due to structural barriers. Structures such as formalisation, centralisation, hierarchy of power, and specialisation can impede the ability of individuals to make independent decisions, thereby diminishing their sense of autonomy, as identified by Daft (2010).

The degree to which job autonomy can be effectively implemented is also significantly influenced by cultural factors. Cultural beliefs, thoughts, and perspectives, which differ from society to society, can significantly influence job autonomy, as explained by Wu et al. (2015). It is intriguing that they discovered that job autonomy is more readily implemented in hierarchical societies than in Western cultures that have historically prioritised individuality. The conventional assumptions regarding autonomy and cultural preferences are challenged by this discovery.

2.4 Work culture

Organisational culture is a fundamental component that affects all facets of employee performance and motivation. Kotter and Heskett (1992) define company culture as the collective beliefs, values, attitudes, and behaviours that influence the manner in which

employees interact with one another, make decisions, and execute their duties. This definition establishes culture as a comprehensive system that permeates all organisational activities.

2.5 Key Performance Indicators and Facilities Management

Key Performance Indicators (KPIs) are indispensable instruments for monitoring and evaluating the efficacy of facility management services. These indicators offer quantifiable benchmarks for performance evaluation and define critical components of service delivery. To achieve successful KPI implementation, it is necessary to pay close attention to pertinent processes, ensure that quantifiable data is accessible, and involve internal staff in the development and monitoring process. Mohammad Awadh and Saad underscore the potential of KPIs to serve as effective motivational incentives when employees are involved in their development and receive consistent communication regarding their significance and potential impact on organisational success.

3.0 METHODOLOGY

3.1 Research Design

This study employs an inductive qualitative approach to investigate the motivations of senior facility management employees and their impact on job performance. Nine senior employees from three different company locations will be interviewed one-on-one, with open-ended questions.

3.2 Data Collection

Data will be gathered through semi-structured interviews with nine senior facility management personnel. The interviews will include open-ended questions that will allow participants to elaborate on their work motivations and the impact of various factors (compensation, relationships with co-workers, job autonomy, and company culture) on their job performance. Interviews will be conducted either via Microsoft Teams or in person. Face-to-face interviews will be recorded using voice memos on a smartphone or digital recorder.

3.3 Research Instrument

The research instrument will be semi-structured, one-on-one interviews conducted via Microsoft Teams or in person. The interview protocol will include open-ended questions that allow for follow-up questions based on the participant's responses. If the interviews are conducted in person, they will be recorded using voice memos and then transcribed for thematic analysis. As a result, voice memos will only be used to record in-person interviews, whereas Microsoft Teams also supports remote/virtual interviews. The key is to record the interviews for accurate transcription and analysis.

3.4 Data analysis

The interview transcripts will be analysed using a thematic approach. The analysis aims to deduce motivational themes and theories solely from the participants' perspectives using an inductive coding process. Common ideas about incentives, social bonds, autonomy, culture, and their impact on performance will be identified. The methodology employs a qualitative approach to collect in-depth insights directly from senior facility management employees via personal interviews, allowing motivational frameworks to emerge from their subjective experiences and perspectives.

3.5 Population/Sample

The target population is senior facility management employees at Facility Management Companies in Selangor, including roles like operations managers, facility managers, and head of department. A purposive, non-probability sampling method is being used. The sample consists of 9 senior facilities management employees from 3 different office locations of an organization in Selangor (3 employees per location).

3.6 Variables

The independent variables appear to be compensation, co-worker relationships, job autonomy, and workplace culture. The dependent variable is senior employee performance within facility companies.

3.7 Procedures

Semi-structured, one-on-one interviews will be conducted with the 9 participants. Interviews will be conducted either face-to-face and recorded with voice memos or remotely via Microsoft Teams. An interview protocol with open-ended questions will be used to allow participants to describe their motivations and perceptions. Thematic analysis will be performed on the interview transcripts to inductively identify recurring themes related to motivation factors and their impact on performance. Strategies like audit trails, reflexive memoing, data triangulation, and peer debriefing will be implemented to enhance reliability, credibility, and confirmability of the qualitative findings. The purposive sampling from multiple sites allows exploring motivational patterns across the organization, while the qualitative interviews and inductive analysis enable developing theoretical frameworks grounded in the participants' perspectives.

4.0 RESULTS AND DISCUSSION

4.1 Participant Response Summary

The survey revealed several facility management employee motivation insights. Most participants said that while a high salary is important for motivation, it is not the only factor. They stressed that good compensation reduces financial stress, but work environment and growth opportunities also affect job satisfaction. Participants found the salary range of RM4,000 to RM12,000 motivating for commercial building facility managers. This range was appropriate, depending on the individual's experience and role responsibilities. Workplace relationships were emphasised throughout the responses. Participants repeatedly said that strong co-worker relationships boost motivation by improving communication, collaboration, and problem solving. They value open, respectful, and constructive feedback interactions because they motivate and create a positive work environment. Motivation also depends on decision-making autonomy. Most participants said they need 80-90% decision-making freedom to manage facility operations and solve problems. This flexibility lets them make their own decisions, which motivates them and leads to more effective and tailored workplace solutions. Work culture may motivate employees the most. Participants' ideal work culture promotes cooperation, accountability, open communication, and mutual respect among all staff levels, regardless of hierarchy. This culture was consistently cited as motivating and necessary for a productive workplace. Beyond these main factors, participants listed several other employee motivation factors. These include company values, work-life balance, management style, workplace fairness, and professional development. Work culture topped most participants' lists of motivational factors, followed by decision-making freedom, co-worker relationships, and salary.

This ranking shows their belief that a healthy work culture helps them work more efficiently and effectively, which boosts job satisfaction and success.

Table 1 Thematic Analysis by Participants

Interview Question	**Participants with Similar Responses**
High salary is important for motivation but not the sole factor, other factors like work environment also matter	P1, P3, P4, P5, P6, P8, P9
Salary range of RM4,000 - RM12,000 considered motivating for facility manager role	P1, P2, P3, P4, P5, P6, P7, P8, P9
Strong relationships with co-workers increase motivation as they facilitate communication, collaboration, and problems. solving	P1, P2, P3, P4, P5, P6, P7, P8, P9
Open, respectful interactions with co workers that involve constructive feedback are motivating	P1, P2, P3, P4, P5, P6, P7, P8, P9
Require high degree of freedom (around 80- 90%) in decision-making for effective operations management	P1, P2, P3, P4, P5, P6, P7, P8, P9
Greater flexibility to act on one's own judgment is motivating for more effective problem-solving	P1, P2, P3, P4, P5, P6, P7, P8, P9
An ideal work culture that promotes cooperation, accountability, open communication, and respect among staff is motivating	P1, P2, P3, P4, P5, P6, P7, P8, P9
Factors like company values, work-life balance, management style, fairness are crucial for motivation	P1, P2, P3, P4, P5, P6, P7, P8, P9
Work culture ranked as the most important factor, followed by decision-making freedom, relationships with co-workers, and finally salary	P1, P2, P3, P4, P5, P6, P7, P8, P9

Table 2 Thematic Analysis by Frequency

Factors	Frequency
Salary as a motivator (but not sole factor), importance of commensurate pay	10
Specific salary range mentioned (RM4,000 - RM12,000)	14
Importance of co-worker relationships for communication, collaboration, problem-solving	15
Open, respectful interactions with co-workers	13
High degree of freedom/autonomy in decision-making (70-100%)	11
Flexibility to act on one's judgment for effective problem-solving	6
Ideal work culture promoting cooperation, accountability, respect	9
Other factors like company values, work-life balance, management style	9
Work culture ranked as most important factor	7

4.2 Discussions

The interview results strongly support the main themes that were found in the literature study about what motivates experienced workers, especially in the facility management sector. In line with research that shows how important fair pay systems are, participants said that a reasonable salary range of RM4,000 to RM12,000 that takes into account experience and workload is motivating, but not the main thing that drives them. Positive relationships with co-workers were found to be very important, as shown in studies that linked supervisor/peer support to better engagement. Participants said that trust, respect, and good relationships were some of the main things that motivated them to work together. In line with research on how to balance growing job autonomy with structural constraints, most of the participants highly valued 80–100% freedom in decision-making as a way to make the most of their expertise. Also, the literature's view on how organisational culture affects employee performance was highly supported. The most important things that motivated people were open communication, mutual respect, accountability, and a good work-life balance. Participants felt that things like leadership that is in line with the organization's ideals, employee recognition, and the chance to grow were motivating and improved performance, even though they weren't directly related to performance metrics.

5.0 CONCLUSION

While a competitive salary is still important, the results suggest that non-monetary motivators such as a good work culture, strong relationships with co-workers, and job autonomy are more important for senior facility management employees' motivation and performance. The most important thing that motivated people was an ideal work environment with open communication, accountability, mutual trust, and respect at all levels, as well as a balance between work and life and recognition for good work. For problem-solving and job satisfaction,

having good relationships with co-workers that let them work together freely was highly valued. People thought that having a lot of freedom and independence, like 80–100% of the decision-making power, was empowering and led to better performance. These senior employees were motivated by fair pay that matched their experience and workload, not just high pay. Salaries between RM4,000 and RM12,000 were suggested as appropriate for senior facility manager roles. Overall, the study shows that creating an interesting organisational culture, helping teams work together, and giving people freedom are important ways to get experienced facility managers to work harder and do their best.

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The Impact of Physical Work Environment Towards Employee Perceptions at Brahim's Food Services

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ABSTRACT

The physical workplace environment (PWE) plays a crucial role in shaping employees' productivity, and this also contributes significantly to the broader goal of sustainable environmental health. This paper will highlight the factor of physical work environment that affect employee at Brahim's Food Services. A poor work environment will have a large impact on the health of its workers and can reduce feelings of excitement, enthusiasm and progress in work. The objective of this study is to to suggest improvement on work environment condition for employee. The research method used is quantitative approach. The sampling size are 66 employees refer by Table Krejie and Morgan.The instruments used is questionnaire by collect data from the office employee across all department at Brahim's Food Services. The analysis technique that been used for this quantitative method is IBM SPSS Software 29.0 version. The finding of this study shows that the work area design was the highest rated factor which employee strongly agree that their workspace is well-designed. Features like ergonomic setup and relaxation areas are highly appreciated and are seen to positively influence their work perceptions.

Keywords: Impact, environment, employee, food, services

1.0 INTRODUCTION

1.1 Research Background

Enhancing employee productivity is a key objective for any organization, contributing significantly to overall success and competitiveness. One common way to measure productivity improvements is by evaluating factors such as reduced absenteeism, fewer instances of employees leaving work early, and shorter or less frequent breaks, which reflect employee engagement and focus (Amofa et al., 2017). However, a crucial aspect that organizations must address is the comfort of the work environment, as a well-designed and comfortable workspace can significantly impact an employee's ability to concentrate, collaborate, and perform tasks efficiently. Investing in a conducive work setting not only enhances physical comfort but also supports mental and emotional well-being, ultimately fostering a more productive and positive workplace culture (Haynes, 2008). The physical environment of a workstation includes various aspects such as the ventilation system, lighting, workspace design, and acoustic system.

1.2 Research Problem

Mutia et al. (2014) reveal that the work environment in an organization can significantly influence worker productivity, a view supported by Desmoda (2016), who found that physical aspects of the work environment such as office space, lighting, color, air quality, music, and noise levels have a notable impact on employee output. Conversely, a poor work environment can negatively affect employee health and diminish motivation, enthusiasm, and progress (Duru & Shimawua, 2017). Similarly, Hogan, Lambert, and Griffin (2013) observed that unfavourable workplace conditions, including physical strain, environmental issues, and

hazards, contribute to reduced employee performance by hindering concentration, creativity, and problem-solving abilities. Additionally, previous research by Sutton and Rafaeli (1987) indicated that factors such as extreme temperatures, inadequate lighting, and overcrowded spaces can elevate stress levels in the workplace.

1.3 Research Aim

To propose strategies for improving employee performance by creating a conducive work environment.

1.4 Research Objectives

i To identify the factors that affect physical work environment towards employee at Brahim's Food Services.

ii To analyse the factors that affect physical work environment towards employee at Brahim's Food Services.

iii To suggest improvement on work environment condition for employee at Brahim's Food Services.

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2.0 LITERATURE REVIEW

2.1 Physical Work Environment

The physical environment includes components of the tangible workplace setting, such as the spatial layout and functionality of the surroundings. Research on the workplace environment is necessary to create ergonomic spaces that ensure employee satisfaction. According to Samson, Waiganjo, and Koima (2015), spatial layout refers to how machinery, equipment, and furnishings are arranged, including their size, shape, and spatial relationships, which can influence the amount and nature of conversations among individuals. Amir (2010) highlighted two main elements related to the physical work environment: the office layout plan and office comfort, both of which impact employee performance depending on how well workers fit within their physical workspace. Furthermore, Samson, Waiganjo, and Koima (2015) emphasized that a better physical workplace environment enhances employee performance and productivity. Kohun (2002), as cited by Samson, Waiganjo, and Koima (2015), stated that a healthy workplace characterized by respect supports employee engagement and fosters a high performance culture that encourages innovation and creativity. Proper elements of the physical work environment, such as suitable furniture and equipment for each employee, are essential to avoid burden and promote comfort, thereby enhancing productivity. Employees are the most valuable asset of any organization, playing a crucial role in achieving success through their performance. When employees perceive that their work environment supports their responsibilities, they are more motivated to perform. Ultimately, organizational success relies on employee performance, which is greatly influenced by a supportive and well-designed workplace environment.

2.2 Lighting

Regardless of building design, natural light is considered the most desired natural feature in the workplace, as its exposure significantly impacts employees' quality of life. The amount of light required varies depending on the type of tasks being performed, whether indoors or outdoors, and this directly affects employee performance either enhancing or diminishing it. Inadequate

lighting, such as high glare, dim lighting, or a lack of natural light, leads to discomfort and distress, ultimately resulting in poor job performance (Gitahi & Maina, 2015).

The brightness of office lighting influences concentration, alertness, and task performance, and modifying its quality can substantially improve the working experience and productivity (Sehgal, 2012). Ali et al. (2015) emphasized that proper lighting in both office and industrial settings is essential for safety and timely, effective task completion. Lighting standards differ across work environments and must be tailored to suit specific job requirements. Additionally, Boyce et al. (2003), as cited by Naharuddin and Sadegi (2013), noted that lighting is one of the physical work environment factors influencing employee performance. Sarode and Shirsath (2012) further explained that poor lighting conditions, such as overly dim or excessively bright environments, can cause eyestrain, headaches, irritability, and reduced productivity. Furthermore, light sources including sunlight can cause glare, unwanted reflections, and shadows that may lead to discomfort and distraction, interfering with the performance of visual tasks.

2.3 Ventilation System

An organization's ventilation system plays a vital role in the productivity and well-being of its employees, as extreme temperatures can significantly impact both physical and emotional states. When the workplace is too hot, it can lead to fatigue, discomfort, and negatively affect employees' mood, while overly cold environments may cause musculoskeletal issues like stiffness and joint pain, ultimately affecting overall health and performance (Rollinson, 2005). These temperature extremes disrupt comfort and focus, hindering task efficiency. In addition to temperature, factors such as air quality and cleanliness also heavily influence the work environment. Dusty or dirty conditions contribute to stress, reduce employee satisfaction, and increase the risk of health problems, emphasizing the need for clean, well-ventilated spaces. Research has shown that poor air circulation and extreme temperatures are major stressors that can decrease performance and raise stress levels (Wickens et al., 2015). Inadequate air quality combined with insufficient temperature control can cause employees to feel unwell and significantly reduce their ability to work effectively.

2.4 Noise

An ergonomic workstation environment must also consider acoustic aspects to ensure employee comfort and well-being, as it allows individuals to perform tasks without noise interruptions. Innovative office designs should incorporate both acoustic control and visual stimulation (Kuijer et al., 2005), using solutions such as acoustic damping devices, glass partitions, acoustic ceilings, and printer cabinets to minimize noise. Noise levels are typically measured in decibels, and human factor studies have shown that excessive or unexpected noise can negatively impact work performance and cause emotional tension (Van Der Voordt et al., 2020). Such disruptions can lead to increased blood pressure, headaches, hypertension, and sleep disturbances (Greenberg, 2004), as well as reduced focus, fatigue, lowered self confidence, strained interpersonal relationships, and heightened workplace stress (Blonna, 2005). Furthermore, prolonged exposure to noise is linked to heart problems, increased absenteeism, fatigue, and psychological stress (Arentze, 2020). The acoustic component of the work environment is shaped by employees' perceptions of noise sources that interfere with task focus, which may include phone conversations, ringing phones, typing sounds, road traffic, or nearby construction activities.

2.5 Work Area Design

An efficient and effective workstation is characterized by its ability to provide a comfortable workspace that supports smooth workflow and enhances employee productivity. A well designed workspace promotes focus, creativity, and collaboration while minimizing stress, whereas poor design can cause discomfort, frustration, and reduced job satisfaction. Sutton and Rafaeli (1987) emphasized that inadequately planned workspaces hinder employee performance and negatively influence the organizational climate, underscoring the need to prioritize ergonomic and layout considerations that directly impact employee well-being and effectiveness. Research further indicates that a congested and cluttered workspace can significantly impair employee performance. Garland et al. (2018) found that cramped environments lead to feelings of overcrowding, reducing both satisfaction and task efficiency. Physical restrictions often contribute to emotional stress, decreasing productivity and limiting employees' ability to concentrate and access essential resources like tools, documents, or effective communication with colleagues, thereby disrupting overall workflow.

3.0 METHODOLOGY

3.1 Quantitative Method

In this study, a quantitative approach known as a cross-sectional survey design was used as the method of investigation. In order to achieve the goal of identifying and assessing the elements that affect employee through physical work environment at Brahim's Food Services from a certain point in time, this decision was made since it is in line with the purpose. Through the application of statistical analysis to the data obtained from the questionnaire, the questions posed by the study will be answered.

3.2 Research Instrument

The research instrument that will be used to collect data for this study is a digital questionnaire administered through Google Forms. Google Forms offers a convenient and efficient way to distribute the questionnaire to participants, allowing for easy access and completion from any device with internet access. This platform is particularly suitable for gathering responses from a large group of employees across different departments within Brahim Food Services. By utilizing Google Forms, the data collection process can be streamline, ensuring that responses are automatically compiled and stored in a central location, making data management and analysis more efficient. The questionnaire are based on independent variable which are lighting, ventilation system, noise and work area design.

The questionnaire contains three sections which are:

i. Section A : Demographic respondent
ii. Section B : Factor that influence physical work environment towards employee at Brahim's Food Services which are lighting, ventilation system, noise and work area design.
iii. Section C : Suggestion for improvement on physical work environment for employee at Brahim's Food Services

3.3 Research Sample

The respondents for this study are office employees from all departments within Brahim Food Services, ensuring a diverse representation across various job functions and responsibilities. The total population consists of 100 employees. To determine an appropriate sample size for

the study, the Krejcie and Morgan sample size determination table was used. According to the table, a population of 100 requires a sample size of 80 to achieve a confidence level of 95% with a margin of error that is statistically acceptable. Selecting 80 respondents allows the study to gather comprehensive insights while maintaining accuracy and generalizability of the findings to the entire office staff.

3.4 Data Analysis Technique

The quantitative data collected through the questionnaire, such as responses to Likert scale items regarding lighting, temperature, noise, and workplace design, will be analyzed using SPSS to generate descriptive statistics. These statistics will include measures such as means, standard deviations, and frequencies providing a clear overview of how employees perceive the physical work environment.

4.0 Results And Discussion

The descriptive statistics were calculated for each item and variable to investigate their levels among the respondents. According to Mohd Najib Abd Ghafar (2003), the three levels of categories based on the mean are low (1.00 – 2.33), medium (2.34 - 3.67), and high (3.68 – 5.00).

Table 1: Descriptive Statistics for Lighting (N=66, Mean=3.6455, SD=0.83153)

Variable	Mean	SD	Level
Lighting			
1. The lighting in my workplace is sufficient for my tasks.	2.42	1.882	Medium
2. Poor lighting negatively affects focus and productivity	4.36	1.159	High
3. Natural lighting enhances concentration and reduces fatigue.	4.59	0.894	High
4. Artificial lighting in workspace is comfortable for long working hours.	2.18	1.597	Low
5. Inconsistent or flickering lighting causes discomfort and eye strain	4.67	0.475	High

Table 1 shows the descriptive statistics for lighting variable. Overall mean for lighting is 3.65, indicating a medium level. Poor lighting negatively affects focus and productivity (mean = 4.36) and natural lighting enhances concentration and reduces fatigue (mean = 4.59) are rated at high level. Meanwhile, the highest level from this variable is inconsistent or flickering lighting causes discomfort and eye strain (mean = 4.67). This shows that flickering lighting is a common problem that affects many employee. Furthermore, the lighting in my workplace is sufficient for my tasks (mean = 2.42) is rated as medium level. Lastly, the lowest rated item is artificial lighting in workspace is comfortable for long working hours (mean = 2.18). This suggest that many employees find the artificial lighting is uncomfortable especially during long working hours, although a few may have different views.

Table 2: Descriptive Statistics for Ventilation (N=66, Mean=2.9030, SD= 0.64521)

Variable	Mean	SD	Level
Ventilation			
1. The ventilation system in workplace ensures good air quality.	4.48	0.504	High
2. Poor air circulation feel uncomfortable and affects productivity.	2.05	1.677	Low
3. Experience discomfort due to stale or stuffy air in workplace.	2.23	1.517	Low
4.The air conditioning or ventilation system is well maintained and functions effectively	4.15	1.438	High
5. Temperature fluctuations throughout the day impact work efficiency.	1.61	0.990	Low

Table 2 shows the descriptive statistics for ventilation variable. Overall mean for ventilation is 2.90 , indicating a medium level. The highest rated item is the ventilation system in workplace ensures good air quality (mean = 4.48), showing that most respondent agreed that the air quality in their workspace is good. Meanwhile, the air conditioning or ventilation system is well maintained and functions effectively (mean = 4.15) is second high item. Other than that, experience discomfort due to stale or stuffy air in workplace (mean = 2.23) and poor air circulation feel uncomfortable and affects productivity (mean = 2.05) are rated as low level. Lastly, the lowest rated item is temperature fluctuations throughout the day impact work efficiency (mean = 1.61), which shows that most respondents disagreed with the statement.

Table 3: Descriptive Statistics for Noise (N=66, Mean=2.5212, SD=0.55123)

Variable	Mean	SD	Level
Noise			
1. Noise levels in workplace allow to focus without distractions.	4.14	1.402	High
2. Background noise such as conversations and office equipment affect concentration.	1.53	0.898	Low
3. Noise from external sources likes traffic and construction disrupts work.	1.24	0.432	Low
4. Need to use headphones or other noise-canceling devices to concentrate at work.	1.38	0.576	Low
5. Organization provides adequate noise control measures	4.32	1.152	High

Table 3 shows the descriptive statistics for noise variable. Overall mean for noise is 2.52, indicating a medium level of impact. The highest rated item is organization provides adequate noise control measures (mean = 4.32), which means most employees agree that organization controls noise well. Meanwhile, noise levels in workplace allow to focus without distractions (mean = 4.14) is rated high. Furthermore, background noise such as conversations and office equipment affect concentration (mean = 1.53) and need to use headphones or other noise cancelling devices to concentrate at work (mean = 1.38) are rated as low level. Lastly, noise from external sources likes traffic and construction disrupts work (mean = 1.24) is rated as lowest level. This indicate that most respondent strongly disagreed.

Table 4: Descriptive Statistics for Work Area Design (N=66, Mean=4.4879, SD= 0.45893)

Variable	Mean	SD	Level
Work Area Design			
1. The workspace is ergonomically designed to support comfort and productivity.	4.26	1.293	High
2. The office layout provides a balance between collaborative and private work areas.	4.35	0.984	High
3. The design of the workstation helps to reduce physical strain and discomfort	4.38	1.078	High
4. The presence of relaxation areas or breakout spaces improves work experience.	4.82	0.389	High
5. The overall design of the workplace positively impacts job satisfaction and efficiency.	4.64	0.485	High

Table 4 shows the descriptive statistics for work area design variable. Overall mean for work area design is 4.49, indicating a high level of impact. The highest rated item is the presence of relaxation areas or breakout spaces improves work experience (mean = 4.82), showing that almost all respondents agreed about the statement. Meanwhile, the workspace is ergonomically designed to support comfort and productivity (mean = 4.26), the office layout provides a balance between collaborative and private work areas (mean = 4.35), the design of the workstation helps to reduce physical strain and discomfort (mean = 4.38) and the overall design of the workplace positively impacts job satisfaction and efficiency (mean = 4.64) also rated as high level item.

The descriptive statistics were analyzed for four main categories of physical work environment factor that affects employee perceptions which lighting, ventilation, noise and work area design. The average means were calculated from the variable to determine which factor that impact most to the employee perceptions through physical work environment as seen in Table 5. As a result, work area design is the highest factor among the others.

Table 5: Mean for variable (N=66)

Variables	Mean
Lighting	3.65
Ventilation	2.90
Noise	2.52
Work Area Design	4.49

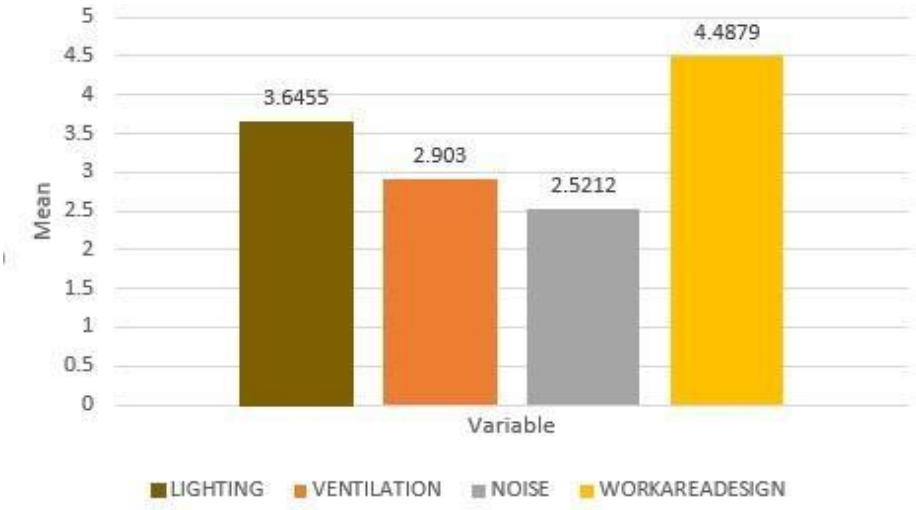

Figure 1 Graph for mean variable

Figure 1 shows graph mean variable for all the variable which are lighting, ventilation , noise and work area design. This study aimed to analyze the factors that affect the physical work environment towards employees at Brahim's Food Services.

1. Work Area Design (Mean = 4.49)

Work area design recorded the highest mean score, indicating that employees at Brahim's Food Services are highly satisfied with the layout and design of their workspaces. The item that received the highest individual mean score in this category was the presence of relaxation areas or breakout spaces improves work experience (mean = 4.82). This suggests that breakout spaces play a critical role in enhancing employee comfort and productivity. According to Jayaweera (2015), a well-designed work environment, particularly one that includes rest areas, significantly influences employee satisfaction and performance. Similarly, Vischer (2007) emphasizes that workspaces that accommodate both focused work and relaxation contribute positively to employees' psychological well-being and productivity.

2. Lighting (Mean = 3.65)

Lighting was the second most positively perceived factor. While not as strong as work area design, the score indicates moderate to high satisfaction. Proper lighting conditions can reduce eye strain, improve alertness, and elevate mood. Past research by Hedge (2000) found that employees working in environments with good natural or artificial lighting reported fewer health complaints and better performance. This implies that lighting, though not the top factor in this study, still holds importance in the physical environment of the workplace.

3. Ventilation (Mean = 2.90)

Ventilation received a neutral to slightly negative rating, showing that this area might require attention at Brahim's Food Services. Poor ventilation can lead to discomfort, reduced concentration, and increased absenteeism. Seppänen et al. (2006) found that better ventilation is associated with improved performance and reduced sick building syndrome symptoms. Therefore, this result indicates an opportunity for the organization to improve air quality and airflow systems to enhance employee health and satisfaction.

4. Noise (Mean = 2.52)

Noise received the lowest mean score, suggesting it is a source of dissatisfaction among employees. High noise levels can interrupt concentration, increase stress, and reduce overall job performance. According to Banbury and Berry (2005), noise in the workplace, especially in open-plan environments or areas with heavy machinery, is consistently linked to lower productivity and job satisfaction. Thus, this finding highlights the need for noise control measures such as soundproofing, use of quieter equipment or noise zoning.

5.0 Conclusion

This study investigated the impact of the physical work environment on employee perceptions at Brahim's Food Services focusing on lighting, ventilation, noise and work area design. The findings revealed that work area design had the most positive influence, especially the presence of relaxation or breakout spaces which significantly enhanced the employee experience. Lighting was moderately well-rated, while ventilation and noise were less satisfactory, indicating areas that require improvement. These results highlight the importance of thoughtful workplace design in supporting employee well-being, satisfaction and overall performance. For management, the findings serve as a practical guide for prioritizing investments in space planning, lighting and environmental comfort to create a more productive and engaging work environment.

Future research can build on this study by exploring a larger and more diverse workforce to improve generalizability. Additional physical factors such as temperature, ergonomics, and aesthetic design could be examined to provide a more comprehensive understanding of environmental influences. Also consider measuring specific outcomes like productivity, stress levels, or employee retention, and using mixed methods or longitudinal designs for deeper insight. These future directions will help organizations better align workplace conditions with employee needs and strengthen the link between physical environment and organizational success.

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The Impact of Total Productive Maintenance Implementation Towards Overall Equipment Effectiveness

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ABSTRACT

The purpose of this study is to investigate how the implementation of Total Productive Maintenance (TPM) affects Overall Equipment Effectiveness (OEE) in educational institutions that are managed by BMES Maintenance Services Sdn Bhd and to suggest practical ways to improve maintenance practices and equipment performance. The issue arises from frequent equipment breakdowns and operational inefficiencies caused by inadequate maintenance approaches. Challenges such as irregular preventive maintenance, poor equipment handling, and low staff engagement contribute to increased downtime and reduced service quality. This study adopts a quantitative research design using a structured questionnaire distributed to respondents from three BMES managed sites. 68 participants were chosen random. The questionnaire using a 5-point Likert scale and the questionnaire was divided into three parts: Part A demographic information, Part B evaluation of TPM pillars and their effect on OEE, and Part C recommendations for TPM improvement. Statistical Package for the Social Sciences (SPSS) software was used to analyse the data. Finding finds out, that safety practices had the most significant impact, followed by planned maintenance, autonomous maintenance and training. The study concludes that effective TPM implementation, supported by structured schedules, continuous staff development, operator involvement, and strong safety protocols, can substantially enhance equipment reliability and operational performance in educational settings.

Keywords: productive, maintenance, implementation, equipment, effectiveness

1.0 INTRODUCTION

1.1 Research Background

This research highlights the maintenance challenges faced at UiTM Seremban, where air conditioning performance issues causing user discomfort were traced to an inadequate chilled water supply. Total Productive Maintenance (TPM), which evolved from industrial applications, offers potential solutions for educational institutions. Sivasankaran (2022) emphasizes TPM's role in measuring and improving equipment effectiveness. Ali (2019) identifies that educational facilities face particular challenges due to infrequent maintenance inspections typically conducted only once a year resulting in prolonged equipment downtime and forcing the use of costly alternatives, such as faculty relying on expensive office printers for critical tasks. Similarly, the Karnataka German Technical Training Institute (KGTTI) in Belagavi, established to function as a finishing school for students in technical fields, faces comparable challenges despite having advanced infrastructure. According to Korgal, Badiger (2019), the institute struggles with poorly maintained equipment, a lack of dedicated maintenance personnel, and underutilized training resources factors that collectively hinder the quality of training and reduce students' readiness for integration into the industry.

1.2 Research Aim

This study aims to propose a comprehensive strategy for implementing Total Productive Maintenance (TPM) to systematically enhance equipment effectiveness and operational efficiency at the BMES company site.

1.3 Research Objectives

The primary research objectives of this study are to:

i. To identify the factor of total productive maintenance that impact on overall equipment effectiveness.

ii. To analyse the factor of Total Productive Maintenance that effect overall equipment effectiveness.

iii. To propose recommendation for optimizing implementation of the total productive maintenance in enhancing overall equipment effectiveness.

2.0 LITERATURE REVIEW

TPM originated in Japan in 1951, developing from preventive maintenance concepts first established in the United States. Nippondenso, a Toyota Group company, pioneered plant-wide preventive maintenance implementation and subsequently received the first TPM certification from the Japanese Institute of Plant Engineers (JIPM) after developing autonomous maintenance practices that engaged machine operators in routine maintenance activities (Soesatijono & Darsin, 2021). Maintenance is conceptualized as "technical, managerial, and administrative activities performed throughout an item's life cycle" with the objective of preserving equipment functionality while enhancing "system effectiveness, availability, and dependability" (Supriatna, 2016; Attajer et al., 2019). The review systematically categorizes maintenance approaches into breakdown maintenance ("fix it when it broke"), planned maintenance ("fix it before brake"), preventive maintenance, predictive maintenance, corrective maintenance, and condition-based maintenance, each serving specific organizational needs and contexts (Soesatijono & Darsin, 2021; Sivasankaran, 2022).

TPM represents a "comprehensive maintenance strategy that integrates all employees within an organization" to optimize equipment performance while pursuing the ambitious goals of "zero accidents, zero waste, and zero breakdowns" (Kitalu, 2021; Anh, 2012). This methodology provides strategic organizational advantages including enhanced employee knowledge, improved internal communications, and more effective equipment management and control systems (Agustiady & Cudney, 2018; San, 2021). The literature identifies four essential pillars of TPM implementation: Autonomous Maintenance, which empowers and equips operators to perform routine maintenance tasks (Robinson & Ginder, 1995; Shirose, 1996; Tajiri & Gotoh, 1992; Nyawa, 2020); Planned Maintenance, which establishes scheduled maintenance procedures based on systematic observation of equipment characteristics (Venkatesh, 2007; Vorne, 2013; JIPM, 1996); Education and Training, which emphasizes continuous workforce development as critical to successful TPM implementation (Marofi, 2014; Venkatesh, 2007); and Safety, Health and Environment, which focuses on eliminating accidents and environmental pollution (Suzuki, 1994). Overall Equipment Effectiveness (OEE) identifying as the primary metric for evaluating TPM implementation success, measuring three critical components: quality, performance, and availability (Nakajima, 1988; Vorne, 2013; Huang et al., 2002; Jeong & Phillips, 2001). This comprehensive framework enables organizations to transition from reactive maintenance approaches to proactive, preventive systems that enhance operational efficiency and equipment longevity. Figure 1 shows the conceptual framework for this study.

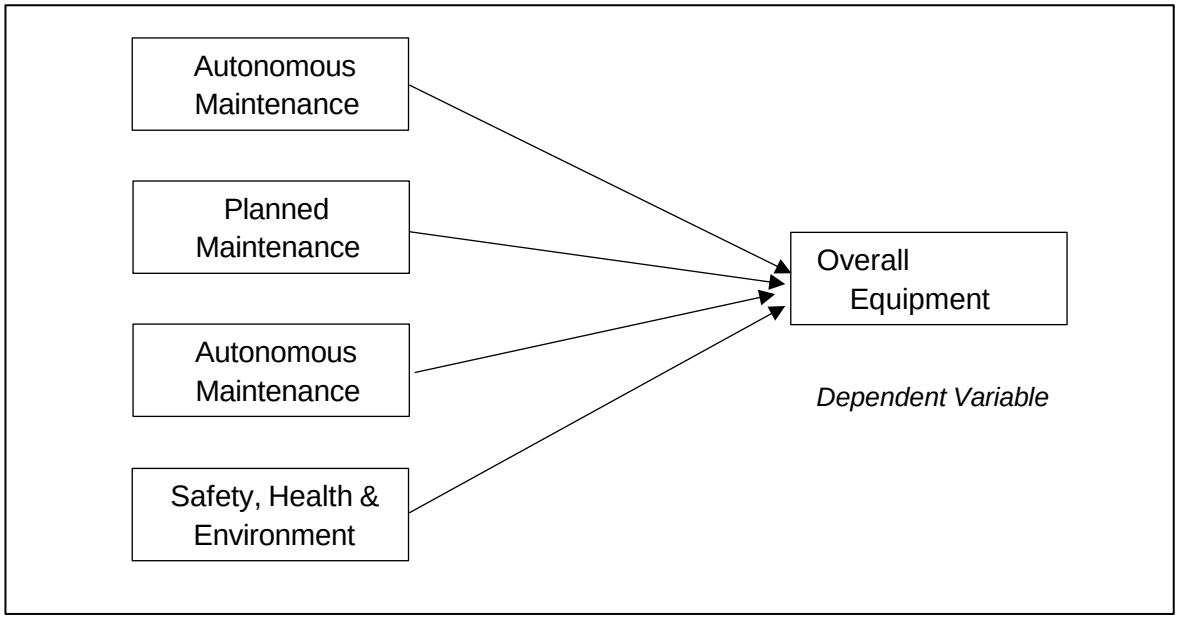

Figure 1: Conceptual Framework

This study employs a quantitative research design using a structured questionnaire to examine the implementation of Total Productive Maintenance (TPM) and its effect on Overall Equipment Effectiveness (OEE) across three BMES-managed sites: UiTM Seremban, UiTM Puncak Alam, and UiTM Rembau. The questionnaire is adapted from Nyawa (2020) and refined to suit the current study's objectives and context. It consists of three main parts: Part A collects demographic information such as gender, age, job position, site location, and length of service; Part B evaluates TPM practices using A 5-point Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree") is used and is structured around four independent variables Autonomous Maintenance, Planned Maintenance, Education and Training, and Safety, Health, and Environment with four questions under each variable (totalling 16 items); and Part C addresses recommendations for TPM improvement through a mix of closed- and open-ended questions. The research uses a cross-sectional time horizon, collecting data at a single point in time. The total population is 75 employees, and a sample size of 63 was determined based on Krejcie and Morgan's (1970) sampling table. Probability sampling was used to ensure equal selection chances, with respondents representing various organizational levels, including top management, middle management, and operational staff. Data analysis is conducted using SPSS, beginning with descriptive statistics such as means, standard deviations, and frequencies, followed by additional analyses and visual presentations to interpret the data and evaluate how TPM influences equipment performance at each site.

4.0 Analysis on Demographic respondent

The respondents' personal information and behaviour-related questions are included in their demographic profile. The purpose of the behaviour-related questions is to assess the respondents' recall of the information at hand (Bryman, 2012). Personal data from the respondents, including gender, age, location, position, and work experience, was also requested for this study. The profile of respondents for this study is displayed in Table 1.

Table 1: Data Respondent

Demography		Frequency	Percentage
Gender	Male	53	77.9
	Female	15	22.1
Age group	20-30	29	42.6
	31-40	24	35.3
	41-50	12	17.6
	Above 50	3	4.4
Position	Top Management	3	4.4
	Middle Management	19	27.9
	Operational	46	67.6
Work experience	Below 1	9	13.2
	1-5	27	39.7
	6-10	21	30.9
	Above 10	11	16.2
Location	UiTM Seremban	26	38.2
	UiTM Rembau	20	29.4
	UiTM Puncak Alam	22	32.4

Table 1 show the respondents (N=68) in this study were predominantly male (77.9%) and primarily from the 20-30 age group (42.6%), followed by 31-40 years old (35.3%), 41-50 years old (17.6%), and above 50 years old (4.4%). Most respondents were from UiTM Seremban (38.2%), followed by UiTM Puncak Alam (32.4%) and UiTM Rembau (29.4%). The majority of respondents held operational positions (67.6%), with smaller percentages in middle management (27.9%) and top management (4.4%). In terms of work experience, most respondents had 1-5 years of experience (39.7%), followed by 6-10 years (30.9%), more than 10 years (16.2%), and below 1 year (13.2%).

4.1 Analysis for Objective One

A reliability analysis using Cronbach's Alpha was conducted for Objective 1 to evaluate the internal consistency of the questionnaire items. The analysis revealed strong reliability across all variables, with Cronbach's Alpha values ranging from 0.790 to 0.858. According to Kiki (2023), a value above 0.6 is considered acceptable, while values exceeding 0.8 are regarded as ideal. The variable with the highest reliability was *Educational & Training*, with an alpha value of 0.858, followed by *Autonomous Maintenance* at 0.846, *Safety, Health & Environment* at 0.804, and *Planned Maintenance* at 0.790. These findings confirm that the questionnaire items are reliable, well-structured, and appropriate for the study. The strong internal consistency suggests that the items effectively capture the intended aspects of Total Productive Maintenance (TPM), ensuring the questionnaire's suitability for further analysis. Table 2 shows below the Cronbach's alpha for each variable.

Table 2: Reliability Coefficients for Each Variable (N=68)

Variables	No. of Items	Item Deleted	Cronbach's Alpha
Autonomous Maintenance	4	-	0.846
Planned Maintenance	4	-	0.790
Educational & Training	4	-	0.858
Safety, Health & Environment	4	-	0.804

4.2 Analysis for Objective Two

The descriptive statistics were also calculated for each item and variable to investigate their level among the respondents. The three levels of categories according to the mean consist of low (1.00 – 2.33), medium (2.34 -3.67) and high (3.68 – 5.00) (Mohd Najib Abd Ghafar, 2003).

Table 3: Descriptive Statistics for Autonomous Maintenance (N=68, Mean=4.184)

Items	Mean	SD	Level
Autonomous Maintenance			
1. Operators/workers are responsible for routine maintenance tasks such as cleaning, lubrication, and inspections.	4.26	.725	High
2. The current maintenance approach allows early detection of potential equipment failure.	4.19	.778	High
3. Encouraging operators/workers to take responsibility for maintenance can improve equipment reliability.	4.34	.704	High
4. Lack of worker involvement in maintenance contributes to frequent equipment failures.	3.94	.844	High

Table 3 displays the descriptive statistics for the Autonomous Maintenance construct. All four items recorded high mean scores, indicating strong agreement among respondents regarding the importance of autonomous maintenance practices. The highest mean score was 4.34 for the item *"Encouraging operators/workers to take responsibility for maintenance can improve equipment reliability"*, followed by 4.26 for *"Operators/workers are responsible for routine maintenance tasks such as cleaning, lubrication, and inspections."* The item *"The current maintenance approach allows early detection of potential equipment failure"* had a mean of 4.19, while *"Lack of worker involvement in maintenance contributes to frequent equipment failures"* recorded the lowest mean at 3.94, though it still falls within the high category. Standard deviations for the items ranged from 0.704 to 0.844, suggesting a relatively consistent pattern of responses among participants.

Table 4: Descriptive Statistics for Planned Maintenance (N=68, Mean=4.221)

Items	Mean	SD	Level
Planned Maintenance			
1. Maintenance is not only done when something breaks but follows a planned schedule.	4.46	.633	High
2. A proper maintenance schedule helps reduce unexpected breakdowns and increases equipment availability.	4.50	.680	High
3. Spare parts are always available when maintenance is needed.	4.15	.778	High
4. Equipment failure is often due to a lack of preventive maintenance.	3.78	.895	High

Table 4 displays the descriptive statistics for Planned Maintenance. All items have a high mean score level, indicating strong agreement among respondents. The item *"A proper maintenance*

schedule helps reduce unexpected breakdowns and increases equipment availability" has the highest mean of 4.50. This is followed by "*Maintenance is not only done when something breaks but follows a planned schedule"* with a mean of 4.46. The item *"Spare parts are always available when maintenance is needed"* has a mean of 4.15. Additionally, *"Equipment failure is often due to a lack of preventive maintenance"* has the lowest mean of 3.78. The standard deviations range from 0.633 to 0.895, suggesting relatively consistent responses across the sample. The overall mean for Planned Maintenance is 4.221 with a sample size of 68 respondents.

Table 5: Descriptive Statistics for Education and Training (N=68, Mean=4.165)

Items	Mean	SD	Level
Education and Training			
1. Workers receive sufficient training on best maintenance practices.	4.03	.668	High
2. Lack of training in equipment operation and maintenance causes frequent machine failures.	4.12	.802	High
3. A systematic training program will help improve equipment maintenance effectiveness at UiTM.	4.25	.632	High
4. To improve worker productivity, relevant training needs to be improved.	4.26	.683	High

Table 5 displays the descriptive statistics for Education and Training. All items have a high mean score level, indicating strong agreement among respondents. The *item "To improve worker productivity, relevant training needs to be improved"* has the highest mean of 4.26. This is followed by *"A systematic training program will help improve equipment maintenance effectiveness at UiTM"* with a mean of 4.25. The item *"Lack of training in equipment operation and maintenance causes frequent machine failures"* has a mean of 4.12. Additionally, *"Workers receive sufficient training on best maintenance practices"* has the lowest mean of 4.03. The standard deviations range from 0.632 to 0.802, suggesting relatively consistent responses across the sample. The overall mean for Education and Training is 4.165 with a sample size of 68 respondents.

Table 6: Descriptive Statistics for Safety, Health & Environment (N=68, Mean=4.379)

Items	Mean	SD	Level
Safety, Health, and Environment			
1. At UiTM sites, accidents involving maintenance are an issue that needs to be prioritized.	4.43	.654	High
2. Implementing a maintenance approach focused on safety can reduce downtime and improve equipment reliability.	4.41	.629	High
3. Environmentally friendly practices like waste management and efficient energy use need to be improved at UiTM.	4.50	.586	High
4. Constant conflict leads to finding job opportunities elsewhere	4.18	.809	High

Table 6 displays the descriptive statistics for Safety, Health & Environment. All items have a high mean score level, indicating strong agreement among respondents. The *item "At UiTM sites, accidents involving maintenance are an issue that needs to be prioritized"* has the highest mean of 4.43. This is followed by *"Implementing a maintenance approach focused on safety can reduce downtime and improve equipment reliability"* with a mean of 4.41. The item

"Environmentally friendly practices like waste management and efficient energy use need to be improved at UiTM" has a mean of 4.50. Additionally, *"Constant conflict leads to finding job opportunities elsewhere"* has the lowest mean of 4.18. The standard deviations range from 0.586 to 0.809, suggesting relatively consistent responses across the sample. The overall mean for Safety, Health & Environment is 4.379 with a sample size of 68 respondents.

Based on Table 7 and Figure 2 below, four key components of Total Productive Maintenance (TPM) implementation Autonomous Maintenance, Planned Preventive Maintenance (PPM), Education and Training, and Safety were analyzed using descriptive statistics to assess their impact on Overall Equipment Effectiveness (OEE). The mean scores for each component were calculated to determine which aspect of TPM contributes most significantly to improving equipment performance. As shown in the graph, Safety recorded the highest mean value (4.38), followed by PPM (4.22), Autonomous Maintenance (4.18), and Education (4.17), indicating that safety practices play the most influential role in enhancing OEE among the TPM components examined.

Table 7: Mean for variable (N=68)

Statistics

		Autonomous	PPM	Education	Safety
N	Valid	68	68	68	68
	Missing	0	0	0	0
Mean		4.1838	4.2206	4.1654	4.3787

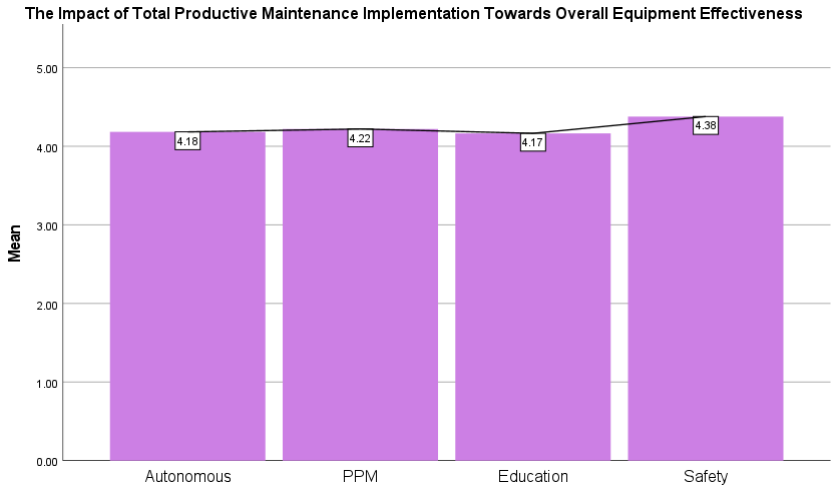

Figure 2 Graph Mean for variable (N=68)

4.3 Analysis for Objective Three

Based on the analysis for Objective three regarding the implementation of Total Productive Maintenance (TPM) at UiTM, it was found that the maintenance system faces several critical challenges. The most significant issues include a lack of training for maintenance staff (64.7%), frequent equipment damage (48.5%), insufficient management support for proactive maintenance (36.8%), and a shortage of spare parts (30.9%). These challenges contribute to frequent equipment breakdowns and operational inefficiencies.

Nearly all respondents (98.5%) agreed that TPM could improve equipment performance at UiTM, confirming a strong consensus on its effectiveness. TPM offers a structured and proactive approach that not only enhances equipment reliability but also improves staff competency and maintenance planning. To ensure successful implementation of TPM, several aspects should be prioritized. These include operator training in basic maintenance (64.7%), systematic spare parts management (44.1%), use of digital tools for equipment monitoring (42.6%), and increased management involvement in maintenance planning (39.7%). A well-organized maintenance schedule and strict adherence to safety procedures (29.4% each) were also emphasized. Table 8 shows the recommendation for implementation TPM.

Table 8: Recommendation for the Implementation TPM

Recommendation for the Implementation of Total Productive Maintenance (TPM)	**Frequency**	**Percentage %**
What are the main challenges in the maintenance system at UiTM?		
Lack of training for maintenance staff	44	64.7
The maintenance budget is insufficient.	17	25
Disorganized maintenance schedule	8	11.8
Shortage of spare parts	21	30.9
Frequent equipment damage	33	48.5
Lack of management support for proactive maintenance	25	36.8
Do you agree that TPM can improve the performance of equipment at UiTM?		
Yes	67	98.5
No	0	0
Half True	1	1.5
What aspects should be prioritized in the implementation of TPM?		
Operator training in basic maintenance (Autonomous Maintenance)	44	64.7
Preparation of a more organized maintenance schedule	20	29.4
More systematic spare parts management	30	44.1
Implementation of stricter safety procedures	20	29.4
Increased management involvement in maintenance planning	27	39.7
The use of digital tools for equipment monitoring	29	42.6

5.0 CONCLUSION

This study demonstrates that the implementation of Total Productive Maintenance (TPM) significantly contributes to enhancing Overall Equipment Effectiveness (OEE) in educational institutions managed by BMES Maintenance Services Sdn Bhd. The analysis revealed that all four TPM pillars Autonomous Maintenance, Planned Maintenance, Education and Training, and Safety, Health & Environment are strongly supported by respondents and positively influence equipment performance. Among these, Safety, Health & Environment (SHE) emerged as the most influential factor, highlighting its critical role in reducing downtime and improving equipment reliability. This finding aligns with Nyawa (2020), who emphasized that improvements in SHE practices lead to significant gains in operational performance by enhancing staff safety and minimizing maintenance-related disruptions. These insights

underscore the need for institutions to prioritize safety initiatives alongside structured maintenance schedules and continuous training. It is recommended that future TPM implementation includes a standardized framework with a strong focus on SHE, supported by preventive maintenance, autonomous maintenance and training program. Further research may examine the long-term benefits of TPM across broader educational and service sectors to validate and extend these findings.

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The Implementation of Risk Management Practices in Facilities and Engineering Management Services (FEMS) Department at Public Hospital

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ABSTRACT
This study investigates the implementation of risk management practices in Facilities and Engineering Management Services (FEMS) departments at three public hospitals in Negeri Sembilan, Malaysia: Hospital Tampin, Hospital Kuala Pilah, and Hospital Jempol. The aim is to assess the current practices and provide recommendations for improvements. Although the Malaysian government has encouraged risk management in the public healthcare sector, past research has identified persisting issues such as inadequate procedural guidance and ineffective implementation. The research used a mixed-methods approach, surveying 97 FEMS staff and interviewing three Facility Managers. The quantitative results show that risk management methods are generally effective, with mean scores of 3.75 for risk identification, 3.74 for risk assessment, and 3.84 for risk monitoring and reporting. However, qualitative findings suggest persistent challenges such as low employee awareness, inconsistent SOPs, and inadequate interdepartmental collaboration. Facility managers offered improvements such as digital reporting systems, employee training, QR code-based issue monitoring, and increased leadership engagement. While FEMS departments have a strong basis in risk management, filling these gaps is critical to creating a more robust and proactive risk governance structure. The study provides practical, actionable recommendations for increasing risk management techniques and improving the overall performance and accountability of Malaysia's healthcare providers.

Keywords: Risk, Management, Hospitals, Facilities, Services

1.0 INTRODUCTION

1.1 Research Background
Risk management has long been embraced in the private sector due to its proven benefits in minimizing risks and ensuring organizational sustainability. However, its implementation in the public sector particularly in Malaysia remains limited and underexplored. This lack of adoption has resulted in inconsistent and often weak risk management practices within public healthcare. Consequently, there is an urgent need to explore how effective risk management can be implemented across the public sector to enhance resilience, promote better governance, and improve resource utilization ultimately restoring public confidence in governmental institutions (Shukri A. & Salim B, 2020).

Public healthcare, especially in developing countries like Malaysia, frequently face systemic challenges such as fraud, corruption, governance failures, and operational inefficiencies. These issues compromise institutional effectiveness and accountability, undermining the quality of public service delivery. Risk management offers a structured approach to addressing these persistent problems by identifying, evaluating, and mitigating risks before they escalate into crises. Through the implementation of robust risk management practices, public sector organizations can strengthen their operational frameworks, enhance transparency, and rebuild trust in their capacity to serve the public effectively (Said & Mahmudul Alam, 2020).

In recent years, the importance of risk management in the public sector has grown considerably due to external pressures such as economic uncertainty, globalization, increased competition, and market liberalization. These factors intensify the vulnerabilities already present in public institutions, particularly for Malaysian Federal Statutory Bodies (FSBs), which are tasked with the dual responsibility of providing quality public services while ensuring sustainable development. Risk management has thus become an essential tool for FSBs, enabling them to manage risks that could derail strategic goals, disrupt service delivery, or threaten long-term viability. Emphasizing risk management as a fundamental component of public sector operations is vital for fostering resilient institutions that can adapt to evolving challenges and consistently deliver value to the public (Bakar & Rasid, 2019).

1.2 Aim and Objectives

The primary aim of this research is to develop effective strategies for enhancing the implementation of risk management practices within the Facilities Engineering Maintenance Services (FEMS) department at public hospitals. By addressing existing gaps and challenges, this study seeks to support the improvement of risk governance, operational efficiency, and service delivery in public healthcare institutions.

To achieve the aim of this research and to address the research questions, the following objectives have been established:

i. To identify the current risk management practices employed within the FEMS department at public hospitals.
ii. To analyse the effectiveness of the existing risk management practices implemented in the FEMS department at public hospitals.
iii. To propose comprehensive and practical recommendations for improving risk management implementation in the FEMS department at public hospitals.

2.0 LITERATURE REVIEW

2.1 Theory

Risk management in healthcare is underpinned by structured theoretical frameworks. The ISO 31000:2018 standard emphasizes integrating risk management across organizational processes, promoting a proactive, rather than reactive, approach. According to ISO (2018), risk management should align with an organization's strategic direction and be customized to its context.

Smith (2020) and Jones & Brown (2021) argue that a structured risk approach is essential in public hospitals, where system failures can impact lives and institutional reputation. Thus, the theory emphasizes holistic and continuous risk monitoring, making it a critical element of hospital governance.

2.2 Risk Management

Risk management is defined as the systematic process of identifying, analyzing, evaluating, and responding to potential threats that may affect an organization’s objectives. In the healthcare sector, especially within public hospitals, these risks include medical equipment failures, system downtimes, maintenance delays, and non-compliance with health and safety regulations. ISO 31000:2018 provides a comprehensive framework to manage such risks effectively.

Aven (2020) and Leitch (2020) highlights the importance of customizing risk frameworks to suit specific environments. In the FEMS context, implementing proactive risk management involves several core activities: identifying potential hazards, assessing the severity and likelihood of risks, developing mitigation strategies (e.g., preventive maintenance schedules, equipment upgrades, and staff training), and monitoring the effectiveness of those strategies.

A structured and integrated approach ensures that all levels of hospital management are aligned and responsive to emerging threats, ultimately reducing operational disruptions and ensuring the continuity of healthcare services.

2.3 Facilities and Engineering Management Services (FEMS) Department

FEMS departments are responsible for maintaining infrastructure vital to hospital functionality. As noted by Salleh (2017) and Noor & Pitt (2019), efficient FEMS operations reduce downtime, extend asset life, and improve service delivery. Risk management in FEMS ensures that maintenance issues do not escalate into safety threats.

In Malaysia, privatization has changed how FEMS is delivered, introducing KPIs and SLAs. While this promotes accountability, it also pressures teams to improve performance despite budget constraints. Emphasizing staff development and adopting advanced asset management tools are crucial for sustainable FEMS operations.

2.4 Effectiveness of Risk Management Implementation

The effectiveness of risk management implementation within FEMS departments is evaluated by its impact on operational safety, regulatory compliance, service continuity, and resource optimization. Effective risk management helps reduce infrastructure breakdowns, improves maintenance response times, and enhances adherence to established protocols.

Key indicators include reduced equipment failure rates, timely resolution of issues, positive audit outcomes, and high compliance with safety and performance standards. Beyond technical indicators, organizational culture plays a vital role. A strong safety culture encourages staff to proactively identify and report risks without fear of blame. Similarly, a culture of compliance ensures that procedures align with regulations and standards like ISO 31000. Support from hospital leadership is also critical; leaders must prioritize risk management, allocate necessary resources, and communicate expectations clearly across departments.

This fosters an environment where risk management becomes a shared responsibility rather than an isolated task. Overall, effective implementation relies on consistent processes, supportive leadership, skilled personnel, and a culture that values safety and continuous improvement.

2.4.1 Risk Management Activities

Risk Management Activities are the core procedures that help an organisation manage risk. These include risk identification, which involves detecting potential threats that may have an impact on organisational operations risk assessment, which assesses the severity and likelihood of identified risks. Meanwhile, risk mitigation/response, which outlines strategies to reduce or respond to risks and risk monitoring, which ensures that risks are continuously tracked and managed (Leitch,2021). These activities constitute the technical implementation of risk management techniques, and they are critical for attaining operational safety and compliance.

2.4.2 Organizational Culture

Organisational culture refers to the common values, attitudes, and practices that shape organisational behaviour, notably in terms of risk management (Nazir & Mazzara, 2022). A strong Safety Culture generates a shared commitment to ensuring a safe working environment, whereas a strong Compliance Culture promotes complying to laws, rules, and internal procedures (Alruwaili & Alsharari, 2021). When these cultural aspects are integrated into the workplace, they raise employee knowledge and participation in risk management practices, resulting in more successful implementation.

2.4.3 Support From Leadership

Leadership support is critical to establishing and sustaining risk management programs. This includes Management Involvement, in which executives actively participate in risk assessment, planning, and decision-making, therefore establishing a good example for the rest of the organisation. Leadership Communication is also critical, requiring senior management to communicate clearly and consistently about risk priorities and expectations. Effective leadership promotes risk management as a strategic priority, supports responsibility, and provides the resources and support needed to carry out risk-related activities (Wong,2020).

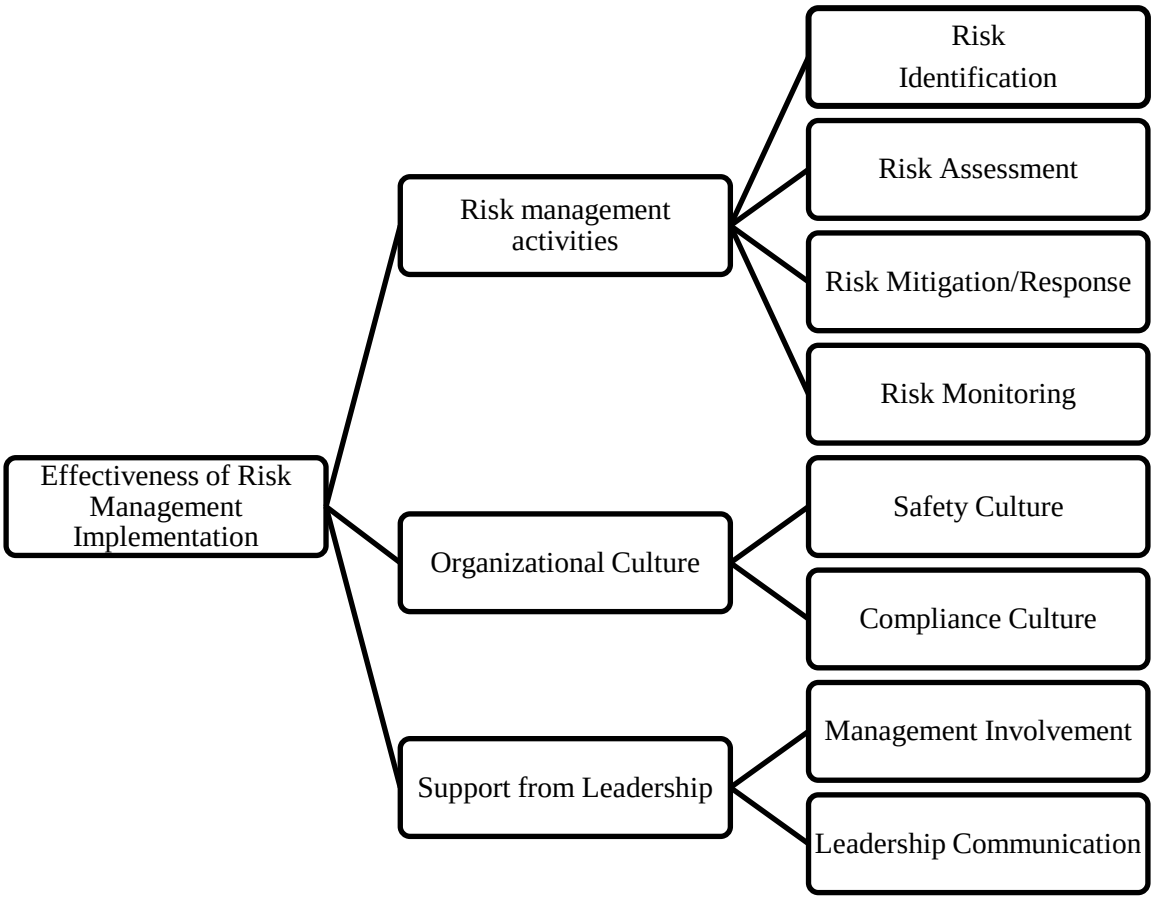

Figure 1 Conceptual Framework

3.0 METHODOLOGY

3.1 Research design

The research design is based on a mixed-methods approach that combines qualitative and quantitative methods to explore the implementation of risk management practices. The qualitative aspect involves semi-structured interviews with key personnel to gather in-depth insights into their experiences, challenges, and perspectives. The quantitative aspect involves structured questionnaires distributed to a broader group within the FEMS departments to collect measurable data on risk management practices, perceptions, and outcomes. This combination allows for triangulation and a deeper understanding of both the statistical trends and contextual realities.

3.2 Data collection method and Instrument

Data is collected from both primary and secondary sources to ensure a comprehensive understanding of risk management practices in the FEMS departments. Primary data is obtained through a combination of semi-structured interviews and survey questionnaires. Semi-structured interviews are conducted with selected personnel who are directly involved in managing risk and maintenance activities. Specifically, interview sessions are held with Facility Managers from Medivest Services in several public hospitals across Negeri Sembilan. These include En. Mohamad Firdaus Bin Arifin from Hospital Tampin, En. Mohd Nor Saiful Bin Ahmad from Hospital Jempol, and En. Mohd Fadil Yaacob from Hospital Kuala Pilah. These interviews are crucial in capturing expert insights into real-world challenges, implementation strategies, and suggestions for enhancing risk management practices in the FEMS environment.

In addition to survey questionnaires are distributed to 97 staff members across FEMS departments in Hospital Tampin, Hospital Jempol, and Hospital Kuala Pilah. The questionnaires are designed to collect quantifiable data on current practices, perceptions, and levels of effectiveness in risk management. This allows for statistical analysis and identification of common trends. The interview was held by 3 facility manager of each hospital.

Secondary data is collected through document analysis, which includes reviewing existing hospital policies, maintenance records, standard operating procedures (SOPs), risk registers, and compliance reports. These documents help validate the information obtained through interviews and surveys, providing a broader context and supporting triangulation in the data analysis process.

Three main instruments are used for data collection: a survey questionnaire, an interview guide, and a document review checklist. The questionnaire is divided into sections covering demographics, risk management practices, organizational culture, and leadership support, using a Likert scale for responses. The interview guide provides open-ended questions that explore implementation challenges and areas for improvement. All instruments are pilot-tested and refined based on expert feedback to ensure clarity and relevance. The pilot test survey questionnaires' Cronbach’s Alpha is 0.807, which is acceptable.

Thematic analysis was performed to examine qualitative data obtained from semi-structured interviews with Facility Managers. The method was divided into six stages: familiarisation, first code development, theme search, review, definition, and final report production. The five key topics that emerged were implementation problems, leadership support, required resources, strategic improvements, and risk culture enhancement, which guided the development of

practical solutions.

Table 1: Number of Respondent responds for data collection

No	Hospital	Number of respondent
1	Hospital Tampin	32
2	Hospital Kuala Pilah	34
3	Hospital Jempol	31
	Total	97

3.3 Population and Sample

The population of this study consists of employees from the FEMS departments of three public hospitals in Negeri Sembilan are Hospital Tampin, Hospital Kuala Pilah, and Hospital Jempol. These hospitals were chosen to represent a range of operational capacities and healthcare service scopes.

The total population of FEMS staff across the three hospitals is 130. Based on Krejcie and Morgan's sample size determination table, a population of 130 requires a minimum sample size of 97 to ensure statistical validity and representativeness. Therefore, a sample of 97 respondents was selected for the quantitative component of the study. 3 Facility manager are been interview for qualitative method.

The sample includes individuals from various roles, such as heads of department, engineers, management, and technicians for quantitative method and Facility manager for Qualitative method. A simple random sampling technique is applied to ensure the inclusion of participants who possess relevant knowledge and experience in risk management and maintenance operations (Sukla,2020).

Table 2: Total population of each FEMS department in each Hospital

No	Hospital	FEMS Staff
1	Hospital Tampin	43
2	Hospital Kuala Pilah	45
3	Hospital Jempol	42
	Total	130

4.0 RESULTS AND DISCUSSION

This section highlights the outcomes of a quantitative survey (n=97) and qualitative interviews with three Facility Managers from Hospital Tampin, Hospital Kuala Pilah, and Hospital Jempol. The study is consistent with the research objectives and identifies patterns, practical obstacles, and possibilities to improve risk management in FEMS departments at public hospitals in Negeri Sembilan.

4.1 Quantitative Findings

Descriptive statistics have been generated for each item and variable to determine their prevalence among respondents. According to Ilhavenil Narinasamy (2021) identified three groups based on mean values: low (1.00 - 2.33), medium (2.34 - 3.67), and high (3.68 - 5.00). Table 3 shows that the overall perception of risk identification across the organisation is high, with a mean score of 3.75 out of 5. The variables associated to risk identification, such as having a systematic approach, promoting employee reporting, and conducting regular assessments, are assessed positively, with averages ranging from 3.61 to 3.98. This indicates that the organisation actively seeks out potential risks, and employees are often encouraged to participate in this process. The standard deviations, which range from 1.22 to 1.24, indicate considerable variety in replies but generally positive impressions.

Table 3: Descriptive Statistics for Risk Identification (N=97, Mean=3.75)

Variable	Mean	SD	Level
Risk Identification			
1. The department has a systematic process to identify risks in facility management.	3.74	1.241	High
2. Employees are encouraged to report potential risks they encounter.	3.84	1.222	High
3. The risk identification process effectively helps in preventing incidents.	3.98	1.244	High
4. Regular risk assessment exercises are conducted to identify potential hazards.	3.61	1.236	High

Table 3 shows that the overall perception of risk identification across the organization is high, with a mean score of 3.75 out of 5. The variables associated to risk identification, such as having a systematic approach, promoting employee reporting, and conducting regular assessments, are assessed positively, with averages ranging from 3.61 to 3.98. This indicates that the organization actively seeks out potential risks, and employees are often encouraged to participate in this process. The standard deviations, which range from 1.22 to 1.24, indicate considerable variety in replies but generally positive impressions.

Table 4: Descriptive Statistics for Risk Assessment (N=97, Mean=3.74)

Variable	Mean	SD	Level
Risk Identification			
5. The organization provides guidelines for assessing risk severity and impact.	3.94	1.368	High
6. Risk assessments are conducted before major maintenance or operational changes	3.57	1.296	Medium

7. Risk mitigation strategies are clearly communicated to staff	3.60	1.115	Medium
8. Adequate resources (equipment, tools, manpower) are provided for risk mitigation.	3.57	1.295	Medium

The results in Table 4 show that the organisation takes a proactive approach to risk assessment, with an overall mean score of 3.74. The variable related to giving recommendations for assessing risk severity and impact had the highest score of 3.94, indicating excellent organisational support in this area. Other factors, such as completing risk assessments before major maintenance or operational changes and properly communicating mitigation methods to employees, obtained moderate values ranging from 3.57 to 3.60. These findings indicate that, while the organisation has some successful risk assessment methods in place, there may be potential for improvement in terms of standardising assessment practices and ensuring comprehensive communication of mitigation measures. The standard deviations, which range from about 1.29 to 1.37, show some variation in responses, highlighting staff assessments of the consistency and efficacy of risk assessment systems.

Table 5: Risk Monitoring and Reporting (N=97, Mean=3.84)

Variable	Mean	SD	Level
Risk Monitoring and Reporting			
9. The organization has an effective system for tracking and monitoring risks.	3.94	1.154	High
10. Risk management reports are reviewed regularly for improvements.	3.75	1.241	High
11. Staff members are encouraged to provide feedback on risk management effectiveness.	4.01	0.933	High
12. Adequate resources (equipment, tools, manpower) are provided for risk mitigation.	3.96	1.334	High

Table 5 shows that risk monitoring and reporting are well-established and highly valued processes inside the organisation, with an average score of 3.84. The organisation appears to prioritise good risk tracking, as demonstrated by high ratings for having an effective risk monitoring system (mean 3.94) and reviewing risk management reports on a frequent basis (mean 3.75). Furthermore, worker input is actively encouraged, with a mean score of 4.01, showing a strong commitment to continual improvement. The availability of necessary resources for risk reduction received a high score of 3.96, demonstrating the organization's commitment to effective risk management techniques. The comparatively low standard deviations (approximately 0.93 to 1.33) indicate that workers have consistent perceptions about these processes. Overall, the organisation has strong risk monitoring and reporting mechanisms that allow for continuous risk management improvements.

Table 6: Mean for Variable (N=97)

Variable	Mean
Risk Identification	3.75
Risk Assessment	3.74
Risk Monitoring and Reporting	3.84

All three sections have been evaluated as "High," indicating overall high performance. The organisation displays effective risk identification, ensuring that any risks are identified and addressed as soon as possible. Risks are carefully examined and appropriate mitigation measures are adopted in terms of risk assessment and mitigation, albeit prior details revealed some difference in specific practises. Notably, risk monitoring and reporting outperforms the other two areas, demonstrating the organization's excellent approach to continual risk tracking and active staff participation in the process.

4.2 Qualitative Finding

Semi-structured interviews were held with three Facility Managers from Hospital Tampin, Hospital Kuala Pilah, and Hospital Jempol. A thematic analysis was used to identify major concerns, leadership positions, resource requirements, and cultural solutions for adopting risk management in the Facility Engineering Maintenance Services (FEMS) department. There were five primary themes identified: (1) Implementation challenges, (2) leadership support, (3) required resources/tools, (4) strategic improvements, and (5) risk culture enhancement to achieve objective 3 : To recommend improvements for risk management implementation in the FEMS department.

Participant:
Participant !: Facility Manager Hospital Tampin
Participant 2: Facility Manager Hospital Kuala Pilah
Participant 3: Facility Manager Hospital Jempol

4.2.1 Challenges in Risk Management Implementation

All responders emphasised organisational and systemic barriers. Participant 1 emphasised the lack of awareness among employees, attributing it to a top-down approach in which risk management is viewed purely as a managerial duty. Participant 2 noted ineffective interdepartmental cooperation and the siloed nature of risk information, which resulted in delayed responses. Similarly, Participant 3 mentioned inconsistencies in SOPs and unreported near-miss situations, indicating that departmental risk perceptions differ. These findings highlight the importance of standardised risk communication methods and ongoing staff training

4.2.2 Leadership Support and Influence

Leadership was universally acknowledged as a critical driver for effective risk management. Participant 1 emphasised the importance of fostering a risk culture through regular meetings and evaluations to encourage proactive behaviour. Participant 2 emphasised the value of visible

leadership in drills and seminars, arguing that direct participation increases accountability.

Meanwhile, Participant 3 proposed reward and recognition mechanisms to encourage risk reporting. These findings indicate that transformational leadership, which includes motivation, recognition, and role modelling, is critical in developing a risk-aware culture.

4.2.3 Resource and Tool Requirements

Technological assistance developed as a common theme. Participant 1 recommended a centralised digital reporting system and technical training for junior staff. Participant 2 proposed risk dashboards and mobile apps to improve communication. Participant 3 proposed predictive maintenance systems and simulated training to help anticipate and manage risks. These suggestions are consistent with current trends in the digital transformation of hospital engineering, where data-driven tools improve efficiency and decision-making.

4.2.4 Strategic Risk Management Improvement

Innovative ideas for improving identification and mitigation efforts were discussed. Participant 1 suggested using QR-code-based real-time reporting and establishing a monthly internal risk committee. Participant 2 developed the notion of "Risk Champions" in departments to help decentralise reporting. Participant 3 emphasised quarterly simulation drills and the visual identification of high-risk equipment. These proactive approaches demonstrate a transition from reactive to preventative risk management models, which improves readiness and responsiveness.

4.2.5 Building a Culture and Safety Awareness

Every participant emphasised the cultural aspect of risk. Participant 1 proposed safety initiatives and small incentives to increase engagement. Participant 2 suggested including safety training into employee onboarding and using real-life case studies. Participant 3 preferred visual tools (dashboards, posters) and safety competitions. Collectively, these approaches seek to normalise safety behaviour and make risk management a shared responsibility for all employees.

5.0 CONCLUSION

This study looked into the implementation of risk management methods in FEMS departments at public hospitals in Negeri Sembilan. The findings found that, while current processes in risk identification, assessment, and monitoring are typically well established, their effectiveness is hampered by communication gaps, inconsistent SOPs, and low staff engagement. Although quantitative results indicated strong overall performance, qualitative interviews with Facility Managers revealed practical issues such as top-down risk perception, a lack of digital tools, and limited leadership visibility in day-to-day risk operations.

To close these gaps and improve implementation, the study recommends four key strategies using digital tools such as QR-code-based reporting and predictive maintenance systems, encouraging leadership participation and recognition systems, decentralising risk governance through departmental Risk Champions and internal committees and cultivating a proactive risk culture through staff onboarding, campaigns, and visual communication tools. These enhancements are crucial for increasing accountability, improving operational safety, and assuring consistent service delivery in public hospital settings.

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The Level of Awareness in Fire Safety Implementation Among Staff at Brahim's Food Service

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ABSTRACT

This study investigates fire safety awareness among staff at Brahim's Food Services, a high risk commercial kitchen environment. The objectives are to assess the current level of awareness, identify influencing factors, and propose improvement strategies. A mixed-method approach was employed, combining structured questionnaire surveys involving 126 staff members across various departments and semi-structured interviews with three department heads. Quantitative data were analyzed using IBM SPSS Version 27.0. Results show a moderately high level of awareness, with strong knowledge of evacuation procedures and fire equipment locations. However, participation in recent fire drills and confidence in emergency response were identified as weaker areas. Reliability analysis confirmed strong internal consistency across variables. Qualitative findings reinforced the survey results, revealing gaps in training frequency, clarity of communication for shift-based workers, and maintenance of fire safety equipment. Interviewees also highlighted the need for inclusive participation, especially for contract staff and non-native speakers. Based on the findings, the study recommends more frequent and practical training, improved communication strategies including multilingual materials, and broader staff involvement in fire safety initiatives. These insights aim to support the development of effective fire risk management strategies in food service operations.

Keywords: Awareness, Fire, Safety, Food, Service.

1.0 INTRODUCTION

1.1 Research Background

Commercial kitchens are dynamic and fast-paced environments where employees are exposed to a variety of fire hazards including cooking equipment, flammable substances, hot surfaces, and complex electrical systems. These high-risk conditions demand a strong and systematic fire safety management plan to prevent workplace accidents, injuries, or disruption to operations. In large-scale food operations such as Brahim's Food Services which supports aviation catering at Kuala Lumpur International Airport (KLIA) even a minor fire incident could cause significant financial losses, reputation damage, or compromise aviation safety. Despite strict legislation and internal safety policies, fire-related incidents may still occur if employee awareness and preparedness are insufficient. Therefore, this study is essential to evaluate the current level of fire safety awareness among Brahim's staff, identify influencing factors, and recommend targeted improvements across departments.

According to the National Fire Protection Association (NFPA), an average of 7,410 structural fires occurred annually in food and beverage establishments between 2013 and 2017 in the United States alone (Klaene & Sanders, 2020). In Malaysia, fire safety in the workplace is governed by the Fire Services Act 1988 and Occupational Safety and Health Act 1994, which mandate regular inspections, emergency plans, and fire drills (Government of Malaysia, 1988; DOSH, 1994). However, a study by Kadar Hamsa (2018) found that

85% of workplaces lacked essential fire safety measures, such as functional emergency exits, while only 30% regularly conducted fire drills.

Despite the implementation of legal frameworks, investigations reveal that there are still major gaps in fire safety compliance and staff involvement. At Brahim's Food Service, the presence of combustible materials, heat, and pressure to meet operational deadlines increases the need for high fire safety awareness. Past incidents and audits highlight insufficient staff engagement in fire drills and a lack of knowledge on fire response protocols, especially among support staff. These issues can result in delayed responses during emergencies, endangering lives and disrupting operations. This study seeks to address these concerns by assessing the current level of staff awareness, analyzing influencing factors, and proposing effective fire safety strategies.

1.2 Aims and Research objective

The primary aim of this study is to evaluate the level of fire safety awareness among staff at Brahim's Food Service and to propose effective strategies for improving fire safety management practices within the organization. This research seeks to understand the underlying factors that influence employee awareness and behaviour in relation to fire safety procedures. To achieve this aim, the study is guided by three main objectives. Firstly, it aims to identify the key factors that contribute to or hinder staff awareness of fire safety management, including aspects such as training, communication, and procedural knowledge. Secondly, the study seeks to assess the current level of fire safety awareness among employees across various departments, allowing for comparative insights into departmental practices. Lastly, based on the findings, the research will propose strategic recommendations to enhance overall awareness, preparedness, and compliance with fire safety protocols throughout the organization.

2.0 LITERATURE REVIEW

Fire safety management within commercial food service environments, such as large-scale kitchens, demands a comprehensive and integrated approach. This includes not only compliance with technical standards but also the cultivation of a safety culture through continuous training, effective communication, and awareness of environmental risks. Multiple studies have emphasized that fire safety awareness is significantly influenced by a combination of organizational practices, staff knowledge, attitudes, and the physical layout of the working environment. Furthermore, the personal characteristics of employees, such as previous safety training or emergency response experience, also play a crucial role in shaping their level of preparedness. An effective fire safety management system, therefore, must consider all these factors holistically to ensure both compliance and genuine staff engagement in fire prevention and emergency response procedures.

2.1 Training and Education

Howarth & Kara-Zaitri (1999) emphasized that fire safety management is only effective when employees are well-trained in procedures and equipment handling. Abdul Hamid et al. (2008) supported this, noting that poor training and lack of routine maintenance contribute to fire risk. At Brahim's Food Service, training programs vary across departments, and some staff still lack basic fire emergency response skills.

2.2 Communication

Subramaniam (2004) stated that effective communication is critical in ensuring successful implementation of fire safety plans. Clear documentation of fire protocols and routine safety

briefings foster a culture of preparedness. Brahim's Fire Disaster Action Plan stresses the importance of both proactive communication and real-time response coordination during fire related emergencies. A study by Kadar Hamsa (2018) in Malaysian workplaces highlighted that communication breakdown during emergencies is a recurring issue, especially in organizations with multilingual staff.

2.3 Work Environment

Beard & Santos-Reyes (1999) explained that a fire-safe work environment integrates hazard detection, fire suppression systems, and accessible safety exits. In many kitchen operations, the physical layout and cluttered work zones can hinder quick evacuation. Brahim's facilities involve both open kitchens and enclosed storage spaces, where proper layout planning is key to fire safety.

2.4 Staff Characteristics

According to Balwi et al. (2004), and supported by Ajzen's (1991) Theory of Planned Behaviour, staff awareness is shaped by personal knowledge, past experiences, and attitudes. The longer a staff has served and the more engaged they are in fire drills, the higher their awareness and preparedness level. Departmental roles also affect exposure to fire risk and safety responsibilities.

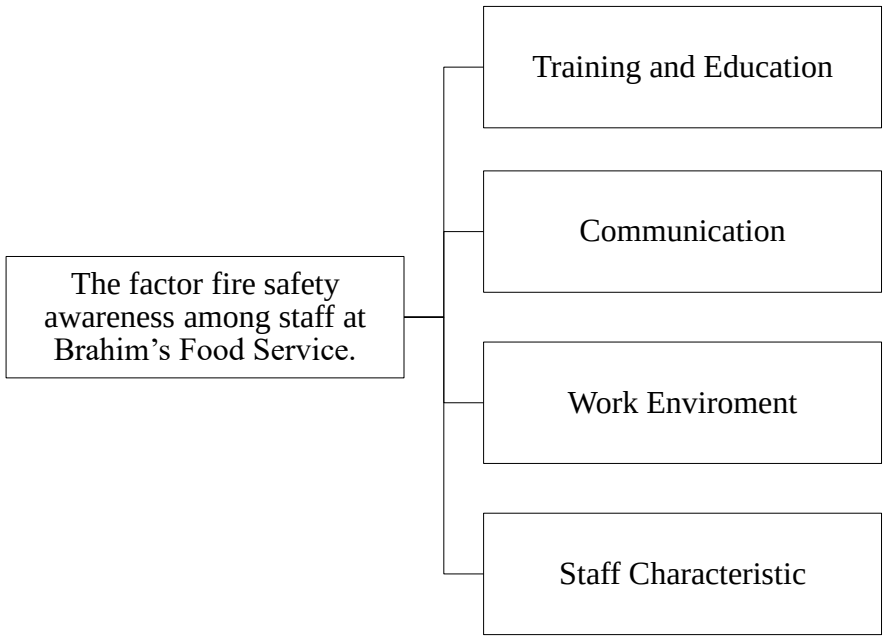

Figure 1 Conceptual framework

Figure 1 illustrates the conceptual framework developed for this study. The framework identifies four key independent variables training and education, communication, work environment, and staff characteristics that are hypothesized to influence the dependent variable, which is fire safety awareness among staff at Brahim's Food Services. These factors were selected based on literature and initial observations at the site, where it became evident that awareness alone is shaped by multiple organizational and individual-level inputs. The framework guides the direction of the research by highlighting the specific domains where interventions can be proposed to enhance overall fire safety implementation in the workplace.

3.0 METHODOLOGY

This chapter outlines the methodology employed to examine the level of awareness in fire safety implementation among staff at Brahim's Food Service. The main objective is to ensure that the research design and methods are consistent with the study's goals, allowing for the generation of valid and reliable findings. The research process includes the design, sampling, data collection, and analysis techniques that have been systematically applied throughout the study. By using a combination of both quantitative and qualitative strategies, this study aims to offer a holistic and evidence-based understanding of fire safety awareness among employees.

This research adopts a mixed-method approach, applying both quantitative and qualitative data collection and analysis techniques to gain a well-rounded understanding of the topic. The abductive reasoning model was applied, allowing patterns from the data to influence the interpretation of fire safety awareness and guide the understanding of possible causes or gaps in implementation.

A structured questionnaire was physically distributed to a total of 126 employees across five departments:

- Facilities Management (20 respondents)
- Kitchen (50 respondents)
- Human Resources (18 respondents)
- Information Technology (12 respondents)
- Safety (26 respondents)

In addition to this, semi-structured interviews were conducted with three Heads of Department (HODs) to collect in-depth insights and managerial viewpoints on fire safety practices.

The questionnaire was divided into four sections: demographic data, identification of key factors of fire safety awareness (including fire safety administration, training, procedural knowledge, and attitudes), individual awareness levels, and a final section for feedback and suggestions. The design of the instrument incorporated Likert-scale, multiple-choice, and open-ended questions to allow for a diverse set of responses.

The Likert scale used ranged from 1 to 5, where:

1= Strongly Disagree
2=Disagree
3=Neutral
4=Agree
5=Strongly Agree

This format enabled the measurement of attitudes and perceptions with a consistent and quantifiable approach.

A pilot study was conducted involving 16 internship students to evaluate the reliability of the instrument. The pilot results yielded a Cronbach's Alpha value of 0.903, indicating excellent internal consistency. Content validity was also verified through expert evaluation by fire safety officers within Brahim's Food Service, ensuring that the instrument was appropriate and aligned with the context of the organization.

In terms of sampling, simple random sampling was used to select general staff members who responded to the questionnaire, ensuring that every employee had an equal probability of selection. For the qualitative component, purposive sampling was applied to select department heads based on their roles and relevance to fire safety implementation. The sample size for the quantitative component was determined using the Krejcie and Morgan (1970) table to ensure statistical representation of the organization's employee population.

Data analysis for the quantitative responses was conducted using IBM SPSS Version 27.0. Descriptive statistics were used to summarize the demographic data and Likert-scale responses, while inferential statistics were applied to identify any significant relationships or patterns among awareness factors. For the qualitative data obtained from interviews, a thematic content analysis was conducted. This allowed for the identification of recurring themes, implementation challenges, and suggestions related to fire safety policy and practice within the organization.

Throughout the research process, ethical considerations were carefully observed. Participants were informed of their rights, the voluntary nature of participation, and the confidentiality of their responses. Informed consent was obtained prior to data collection, and no personal identifiers were used in the reporting process. These measures ensured that the research complied with ethical standards and upheld the integrity of the data collection process.

4.0 RESULTS AND DISCUSSION

4.1 Descriptive Statistics (Quantitative Data)

The descriptive statistics were calculated for each item and variable to investigate their ranking among the respondents.

Table 1: Descriptive Statistics for Fire safety management (N=126)

No	Variable (Training and education)	Mean	SD	Rank
1	I have been given fire safety training periodically by the management.	3.75	0.630	High
2	I understand the fire safety procedures resulting from the training that has been conducted.	3.87	0.632	High

3	The education program on fire safety helps increase my awareness.	3.87	0.683	High
4	I can apply the knowledge learned in fire safety training to real situations	3.80	0.609	High
5	I can act correctly in the event of a fire as a result of the training I have received.	4.03	0.521	High
6	The training provided previously has helped me understand my responsibilities during an emergency.	4.02	0.534	high

Table 1 shows the mean and standard deviation for the variable "Training and Education." The results indicate a moderately high level of agreement they have received adequate training. (M = 4.02, SD = 0.534).

Table 2: Descriptive Statistics for Fire Training (N=126)

No	Variable (communication)	Mean	SD	Rank
1	Information about fire safety is communicated clearly by the management.	3.81	0.629	High
2	I know who I need to report any fire risks at the workplace.	3.98	0.577	High
3	Notices and announcements regarding fire safety are easily accessible to staff.	3.99	0.556	High
4	I often receive briefings on fire safety from the supervisor or management.	3.92	0.529	High
5	I always know the latest information related to fire safety as conveyed by the management.	3.98	0.572	High
6	I can act based on the safety instructions provided by the management.	4.03	0.518	high

Table 2 shows the mean and standard deviation for the variable "Communication." The results indicate a moderate high level of agreement they have received good information. (M = 4.03, SD = 0.518).

Table 3: Descriptive Statistics for Knowledge of security measures (N=126)

No	Variable (work environment)	Mean	SD	Rank
1	My workplace is equipped with sufficient and easily accessible fire extinguishers.	3.96	0.569	High
2	Emergency exits and fire escape routes in my workplace are clearly marked.	3.99	0.527	High
3	A tidy and clean work environment helps reduce the risk of fire.	4.00	0.563	High
4	I am confident that my workplace has an effective fire safety system.	4.04	0.496	High
5	I know the location of safety equipment and exit routes at the workplace.	3.99	0.527	High
6	I feel that my workplace provides an environment that supports fire safety actions.	4.08	0.485	High

Table 3 shows the mean and standard deviation for the variable "work environment." The results indicate a moderate high level of agreement their work environment are in good condition.(M = 4.08, SD = 0.485).

Table 4: Descriptive Statistics for Attitude to fire safety (N=126)

No	Variable (staff characteristic)	Mean	SD	Rank
1	I am always aware of fire hazards in the workplace.	4.00	0.471	High
2	I am responsible for ensuring that fire safety measures are followed while working.	4.00	0.504	High
3	I am ready to take swift action in the event of a fire	3.98	0.495	High
4	I am always aware of situations that could cause fires.	4.00	0.524	High
5	I am ready to assist colleagues in the event of a fire.	4.08	0.485	High

Table 4 shows the mean and standard deviation for the variable "staff characteristic." The results indicate a moderate high level of agreement they very aware about fire safety. (M = 4.08, SD = 0.485).

4.2 Mean For each variable

The descriptive statistics were analyzed for four main categories of improvements to the management practices of fire safety at Brahim Food Service to enhance the execution of fire safety procedures. The average means were calculated from the variable to determine which practice that impact most to the government personnel toward fire safety management as seen in Table 5.

Table 5: Mean for variable (N=126)

No	Variable	Mean	SD	Rank
1	Training and education	3.89	0.60	High
2	Communication	3.95	0.56	High
3	Work environment	4.01	0.53	High
4	Staff characteristic	4.01	0.50	High

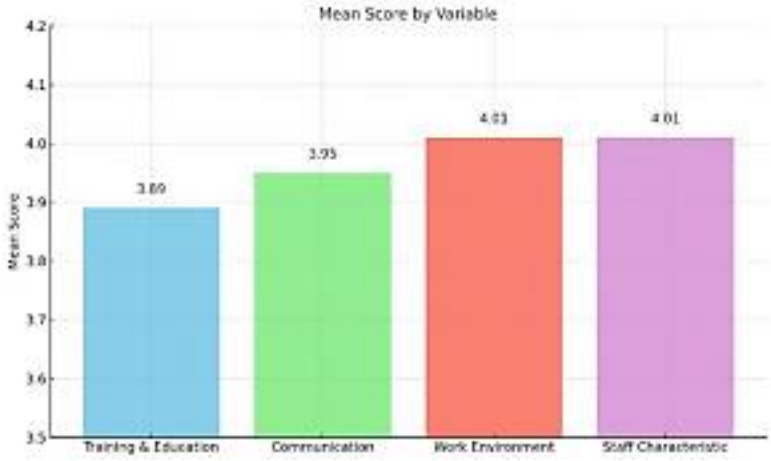

Figure 2: Graph Mean for variable (N=126)

Figure 2 presents the mean scores of the four independent variables that influence fire safety awareness among staff at Brahim's Food Services. The results show that Work Environment and Staff Characteristics recorded the highest mean scores at 4.01, indicating a strong agreement among respondents that these factors significantly contribute to their fire safety awareness. This is followed by Communication with a mean score of 3.95, and Training and Education with 3.89, which although slightly lower, still reflect a generally positive perception. These findings suggest that while all four factors are considered important, improvements in training initiatives could further strengthen staff preparedness and understanding in fire safety implementation.

4.3 Thematic Analysis by Participant.(Qualitative Data)

The thematic analysis from the interviews identified six key themes are fire safety campaigns, training programmes, awareness efforts, training frequency, staff participation, and staff knowledge. These themes emerged consistently across all three participants, who were Heads of Department (HODs) from Facilities Management, Kitchen, and Safety departments. The responses reflected both shared strengths and department-specific challenges. For instance, while all departments acknowledged the importance of fire drills and safety briefings, differences were noted in training frequency, staff responsiveness, and the practicality of safety measures. Thematic coding revealed that each department approached fire safety based on their operational risks, such as electrical hazards in maintenance and oil-related fire risks in the kitchen. This analysis provides deeper insight into organizational practices, complementing the quantitative data and reinforcing the need for targeted fire safety interventions.

Table 6: Thematic analysis

Theme	P1	P2	P3
Fire Safety Campaigns	Conducted briefings and safety talks.	Used posters and briefings.	Gave verbal explanations and display posters.
Training Programs	Basic training yearly, extinguisher handling.	Training on electrical risks.	Specific training on kitchen fires and oil handling.

Awareness Efforts	Full fire drills for all staff.	Hands-on training with fire equipment	Drills focused on kitchen area response.
Training Frequency	Twice yearly, suggested to increase.	Suggested regular schedule.	Suggested practical training every 3 months.
Staff Participation	Good participation, but some take it lightly.	Mixed engagement among staff.	High participation due to daily fire risks.
Staff Knowledge	Understand basics, need regular refreshers.	Know how to use tools, audits needed.	Know proper actions and extinguisher usage.

5.0 CONCLUSION

The analysis of qualitative data obtained through interviews reinforces the findings from the quantitative survey. Overall, staff at Brahim's Food Services demonstrate a high level of awareness regarding fire safety procedures. Most employees are knowledgeable about basic response actions, and departmental initiatives such as training sessions and safety briefings are in place. Future research should focus on the effectiveness of fire safety training across different staff categories, including contract and shift-based workers.

Nonetheless, several critical gaps were identified. These include the irregular frequency of fire drills and training, inconsistent communication of fire safety protocols across different shifts, and concerns regarding the maintenance of fire equipment. The interviews also highlighted challenges in reaching contract staff and non-native speakers, pointing to the need for more inclusive safety communication methods.

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The Relationship Between Occupant Satisfaction and Space Utilization in Digital National Berhad Offices at Tun Razak Exchange (TRX), Kuala Lumpur

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ABSTRACT
This study aims to examine the relationship between space utilization and occupant satisfaction in the Digital National Berhad (DNB) offices located on floors 12 and 25 of the TRX Tower, Kuala Lumpur. The main objective is to enhance strategies that optimize both space utilization and occupant satisfaction. The issue addressed in this research stems from ongoing challenges in achieving high levels of employee satisfaction due to poor space allocation, lack of privacy, and inefficient workspace designs. Despite substantial investments in office spaces, many organizations face difficulties optimizing these areas to balance space efficiency and occupant comfort. In DNB's case, the open layout concept presents opportunities for collaboration but also raises concerns about distractions and lack of personal space. The research applies a mixed method approach by using questionnaires and observation to gather data on occupant satisfaction and space utilization. Stratified random sampling was employed across four zones within the two selected floors. The analysis reveals that only layout flexibility shows a significant and strong positive relationship with space utilization. Privacy and occupancy rate do not have significant effects. The study concludes that implementing adaptable space layout and enhancing privacy can substantially improve employee comfort and productivity, leading to more effective facilities management strategies.

Keywords: relationship, occupant, space, satisfaction, utilization.

1.0 INTRODUCTION

1.1 Research Background
The main purpose of building facilities is to fulfil the needs of its users (Doulos et al., 2020). Buildings that successfully satisfy user demands are seen as more enjoyable and conducive to well-being, according to research that continuously demonstrates a significant relationship between occupant satisfaction and productivity (Agha-Hossein et al., 2013; Norazman et al., 2023; Thomas, 2010). Increased employee productivity has been positively correlated with occupant satisfaction with the workplace, highlighting the importance of well-planned and maintained workplaces (Altomonte et al., 2020; Cheung et al., 2021; Huizenga & Arens, 2002). Even with these realisations, it is still difficult to keep building occupant satisfaction levels high, especially when it comes to physical factors like indoor environmental quality, energy efficiency, and space utilisation (Doulos et al., 2020; Norazman et al., 2023). Efforts to address important performance issues are frequently hampered by ineffective user satisfaction and resource exploitation documentation and review procedures (Doulos et al., 2020; Hadjri & Crozier, 2009). Assessing building performance from the viewpoint of its occupants is essential for guaranteeing long-term efficiency and user comfort, given the sizeable percentage of organisational costs associated with salaries in comparison to operating and rental expenses (Al Horr et al., 2016; Cheung et al., 2021). These issues are the main topic of this study in relation to Digital National Berhad's (DNB) offices located on floors 12 and 25 of the TRX Tower in Kuala Lumpur. These floors, which are distinguished by their contemporary open-layout design, provide the framework for investigating the intricate connection between occupant happiness and space utilisation.

1.2 Aim and Research Objective

This research aims to explore the relationship between space utilization and occupant satisfaction in Digital National Berhad (DNB) offices at TRX, Kuala Lumpur, providing insights into how facilities management practices can be optimized. The objectives are to identify the primary factors contributing to the relationship between occupant satisfaction and space utilization, to analyze current space utilization practices and their impact on occupant satisfaction, and to enhance strategies that optimize both space utilization and occupant satisfaction in the DNB offices.

2.0 LITERATURE REVIEW

2.1 Space Utilization

Buildings are fundamentally designed to fulfil the functional and emotional needs of their occupants, significantly influencing their satisfaction and productivity (Doulos et al., 2020). Research highlights that environments tailored to user preferences enhance comfort and efficiency, which are crucial for well-being (Agha-Hossein et al., 2013; Norazman et al., 2023). Key factors such as spatial design, environmental comfort, and layout flexibility play a vital role in occupant satisfaction, with studies indicating that well-designed spaces lead to higher productivity and engagement (Cheung et al., 2021). The evolution of modern workplaces towards open layouts and collaborative areas reflects a growing recognition of the importance of user-centred design, which fosters a positive experience and enhances organizational outcomes (Yang et al., 2021). Ultimately, prioritizing both the physical and emotional needs of users in building design is crucial for promoting overall satisfaction and productivity, leading to more successful workspaces (Agha-Hossein et al., 2013; Altomonte et al., 2020).

2.2 Key Factors Influencing the Relationship Between Space Utilization and Occupant Satisfaction

Modern office environments face significant challenges, including insufficient social areas, inadequate workspace, and limited layout flexibility, which create a disconnect between workplace design and employee needs (Artan et al., 2022). The lack of social spaces hinders collaboration and community, leading to feelings of isolation among employees, which can negatively impact team dynamics and innovation (Estreder et al., 2021). Furthermore, overcrowded workspaces reduce comfort and concentration, increasing stress and absenteeism. Rigid office layouts fail to accommodate diverse work styles and changing team dynamics, while flexible designs enhance collaboration and individual productivity (Smith, 2019).

Kwon (2020) highlighted the significant link between employee satisfaction and productivity, asserting that a conducive workplace environment characterized by comfort, privacy, and flexibility plays a crucial role in enhancing employee efficiency and engagement. Satisfied employees tend to perform better, while a lack of privacy and territorialism can lead to stress and frustration, ultimately diminishing satisfaction and productivity (Smith, 2019). Research indicates that perceived violations of personal boundaries, especially in open-plan offices, can exacerbate feelings of dissatisfaction and hinder performance (Artan et al., 2022). Conversely, environments that offer privacy and flexible work arrangements are linked to higher satisfaction and productivity levels (Altomonte et al., 2020). These insights underscore the importance of thoughtful workplace design in fostering employee well-being and organizational success, suggesting that organizations should prioritize customizable workspace strategies to meet diverse employee needs (Kent et al., 2022)

Space utilization is a crucial aspect of facilities management, urban planning, and organizational development, focusing on the efficiency and effectiveness of how spaces are used. According to Abdullah et al., (2019), it can be measured through frequency and occupancy rates, where the frequency rate indicates how often a space is actively used compared to its availability, while the occupancy rate reflects the extent to which a space's capacity is utilized. This dual approach highlights inefficiencies that can arise from poor space planning or scheduling mismatches, leading to increased operational costs despite the spaces being available (Kent et al., 2022). By effectively managing these metrics, organizations can optimize space allocation, save costs, and enhance user satisfaction, ultimately leading to better infrastructure investments and avoiding unnecessary expansions (Kulkarni et al., 2024). In summary, integrating space utilization metrics into strategic planning is essential for organizations to create environments that meet the needs of employees and stakeholders while maximizing operational efficiency (Artan et al., 2022; Candido et al., 2019).

3.0 METHODOLOGY

This research aims to understand the relationship between occupant satisfaction and space utilization by examining key factors such as privacy, layout flexibility, and occupation rates in Digital National Berhad (DNB) offices in Kuala Lumpur as shown in table 1. It uses a mixed method approach, including questionnaires and direct observations, to gather data from 139 employees on floors 12 and 25. The target population is diverse and includes a 95% confidence level and a ±5% margin of error, the required sample size is calculated to be approximately 102 respondents. The study aims to provide actionable insights into optimizing workplace environments based on occupant feedback. Descriptive analysis will be conducted using SPSS to summarize and interpret key trends and distributions related to variables studied, such as mean satisfaction scores, standard deviations, and frequency distributions across privacy, layout flexibility, occupancy rate, and perceived space utilization efficiency. The research methodology is summarized and illustrated in the flow chart as shown in the figure below.

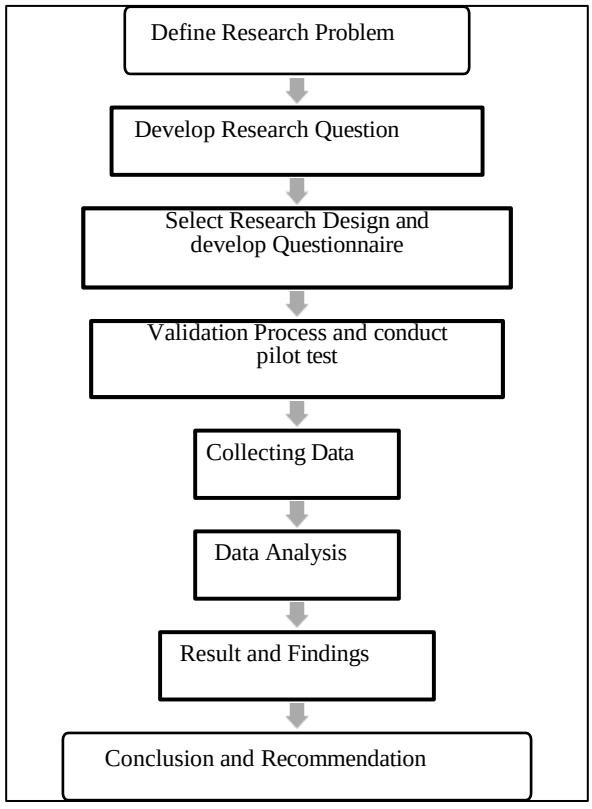

Figure 1: Flow chart of methodology process.

Table 1: Variable Reability Test

Variables	No. of Item	Item Deleted	Cronbach's Alpha
Layout Flexibility	5	-	0.847
Privacy	5	-	0.777
Occupancy Rate	5	-	0.776
Occupant Satisfaction	3	-	0.795

4.0 RESULTS AND DISCUSSION

The demographic profile of the respondents contains their personal information and questions related to their behaviour. The questions that are related to the respondents' behaviour are intended to assess their ability to recall the information (Bryman, 2012). This study also requested for the respondents' personal information such as gender, working years, occupation and often working time in the office. Table 2 shows the respondents' profile for this study.

Tables 2: The respondents' profiles for this study

Demography		**Frequency**	**Percentage**
Gender	Male	48	47.1
	Female	54	52.9
Working Years	<1 Years	13	12.7
	1 – 4 Years	69	67.6
	5 – 9 Years	20	19.6
Occupation	Executive	3	2.9
	Manager	11	10.8
	Support Staff	88	86.3
Often Working Time in the Office	Daily	73	71.6
	3 – 4 Times per Week	27	26.5
	1 – 2 Times per Week	2	2.0

4.1 Descriptive Analysis

The descriptive statistics were also calculated for each item and variable to investigate their level among the respondents. The three levels of categories according to the mean consist of low (1.00 – 2.33), medium (2.34 -3.67), and high (3.68 – 5.00) (Mohamad Najib Abdul Ghafar (2013), 2013).

Table 3: Descriptive Statistics for Variables

Descriptive Statistics				
	N	Mean	Std. Deviation	Level
Occupant Satisfaction	102	4.33.66	.57924	High
Layout Flexibility	102	3.0608	.59555	Medium
Privacy	102	4.2118	.53163	High
Occupancy Rate	102	3.5255	.53616	Medium

In table 3 the item has the highest level of variables "Privacy" (Mean=4.2118). On average, occupant reported engaging in privacy at a high level. The (Standard deviation=0.53163) suggests some variability in the level of privacy among occupant. The level of variables "Layout Flexibility" (Mean=3.0608), indicates that, on average, occupant layout flexibility is at a relatively medium level. The (Standard deviation=0.59555) suggests that there is not much variability in layout flexibility among occupant. For variables "Occupancy Rate" (Mean=3.5255). On average, occupant possess a medium level of occupancy rate. The (standard

deviation=0.53616) indicates some variability in cognitive control among occupant. Layout flexibility and occupancy rate are both reported at medium levels on average, whereas privacy is at a high level. There is some variability in layout flexibility and occupancy rate among occupant, while privacy shows more variability.

4.2 Correlation and Regression

A correlation analysis was used on the relationship between privacy, layout flexibility, and privacy with occupant satisfaction. The Pearson correlation coefficient is a measure of the strength and direction of association that exists between two variables measured. The correlation coefficient (r) is a value that measures the direction and strength of a relationship between two variables 137 (Kimberlin, 2019). The r value ranges from +1.00 to -1.00 and the strength of the correlation is based on (Chua YP, 2013).

Table 4: Size and Strength for correlation

Size of Correlation	Strength of Correlation
0.91 until 1.00 or -0.91 until -1.00	Very Strong
0.71 until 0.90 or -0.71 until -0.90	Strong
0.51 until 0.70 or -0.51 until -0.70	Moderate
0.31 until 0.50 or -0.31 until -0.50	Weak
0.01 until 0.30 or 0.01 until 0.30	Very Weak
0.00	No correlation

Table 5: Relationship between Privacy, Layout Flexibility, and Privacy with Occupant Satisfaction

Correlations

		Occupant Satisfaction	Privacy	Layout Flexibility	Occupancy Rate
Occupant Satisfaction	Pearson Correlation	1	.143	.949**	.011
	Sig. (1-tailed)		.076	.000	.455
	N	102	102	102	102
Privacy	Pearson Correlation	.143	1	.169*	.414**
	Sig. (1-tailed)	.076		.045	.000
	N	102	102	102	102
Layout Flexibiity	Pearson Correlation	.949**	.169*	1	.042
	Sig. (1-tailed)	.000	.045		.338
	N	102	102	102	102
Occupancy Rate	Pearson Correlation	.011	.414**	.042	1
	Sig. (1-tailed)	.455	.000	.338	
	N	102	102	102	102

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

H1: There is a very weak and statistically non-significant relationship between privacy and space utilization.

H2: There is a very strong and statistically significant relationship between layout flexibility and space utilization.
H3: There is no significant relationship between occupancy rate and space utilization.

Based on Table 4, the relationship between layout flexibility and space utilization is very strong (r = 0.949). The relationship is also significant at the 0.01 level (p = 0.000). Therefore, we accept the hypothesis that there is a significant positive relationship between layout flexibility and space utilization. The variable privacy shows a very weak relationship with space utilization (r = 0.143) and is not significant (p = 0.076). Therefore, we reject the hypothesis that there is a significant relationship between privacy and space utilization. In addition, the relationship between occupancy rate and space utilization also shows no relationship (r = 0.011) and is not statistically significant (p = 0.455). Therefore, we also reject the hypothesis that there is a significant relationship between occupancy rate and space utilization.

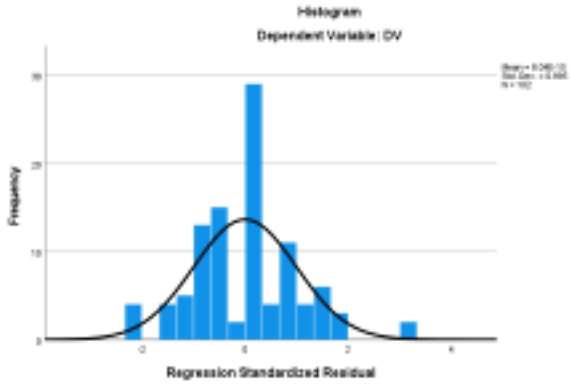

Figure 2: Histogram of Variables and Occupant Satisfaction

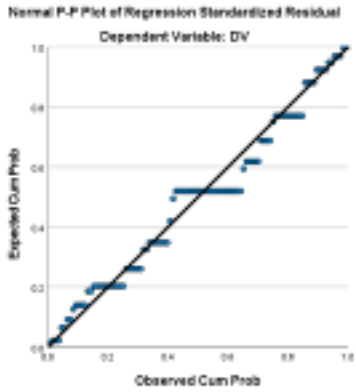

Figure 3: Linear of Variables and Occupant Satisfaction

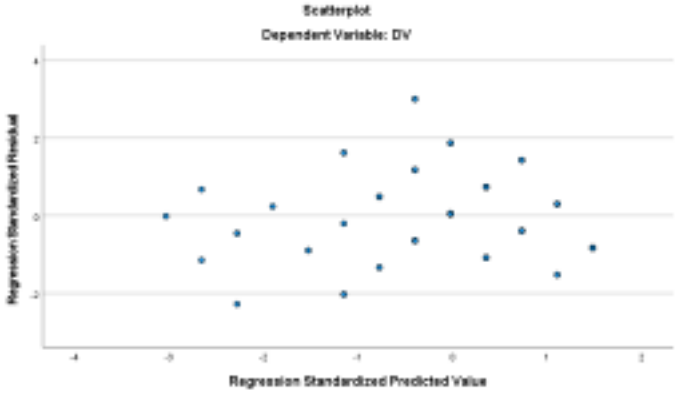

Figure 4: Scatterplot of Variables and Occupant Satisfaction

H1: Privacy and Space Utilization
Based on table 5, the relationship between privacy and space utilization in the office setting is very weak and not statistically significant. Although there is a slight positive correlation ($r = .143$), the p-value of .076 indicates that this relationship does not reach the standard level of statistical significance ($p < 0.05$). This suggests that increased privacy does not significantly influence how occupants perceive the space is utilized. In a modern open-layout office environment, privacy may not be a dominant factor affecting space utilization because employees may adapt to open, collaborative settings even if privacy is limited.

H2: Layout Flexibility and Space Utilization
Based on table 5, the study's findings layout flexibility has a very strong and statistically significant positive relationship with space utilization ($r = .949$, $p < 0.01$). This indicates that as the flexibility of the office layout increases, occupants perceive the space as being better utilized. Flexible layouts likely allow for easier reconfiguration of workspaces to meet different needs, enhance comfort, and support various working styles, leading to higher occupant satisfaction. This finding implies that layout flexibility plays a critical role in maximizing the effectiveness and usability of space in the workplace.

H3: Occupancy Rate and Space Utilization
Based on table 5, the analysis shows that the occupancy rate has virtually no relationship with space utilization ($r = .011$, $p = .455$). This correlation is extremely weak and not statistically significant, suggesting that the number of people using the space does not significantly impact how well the space is perceived to be utilized by the occupants. One possible reason is that occupancy rate alone does not reflect how efficiently space is organized or how well it meets users' needs. Even with a high or low occupancy rate, space may still be underutilized or inefficient if the design does not support user activities effectively.

4.3 Observational Data Analysis
In addition to the questionnaire responses, a workspace observation was conducted on Floors 12 and 25 of the Digital Nasional Berhad (DNB) TRX office. The purpose was to evaluate the current space utilization setup and compare it against Malaysian workplace standards. Each workstation in the observed open-plan office consisted of a shared table measuring 3.0 meters in length and 0.75 meters in width, used by three employees. This translates to approximately 1.0 meter of desk length per person and 0.75 m^2 of surface area. When estimating the total workspace including chair space and movement allowance (1.5m × 1.5m), the average floor area per employee is approximately 2.25 m^2.

Table 6: Data Collect on Observation Compare to DOSH Malaysia Standard

Aspect	Observed Setup	DOSH Malaysia Standard	Status
Desk length per person	1.0 meter	1.2 – 1.5 meters	Below standard
Floor area per person	~2.25 m²	4.65 m² minimum	Below standard
Desk width	0.75 meter	0.75 – 0.80 meter	Meets standard
Privacy & spacing	Minimal; open layout, no zoning	Recommended: visual/acoustic zoning	Below standard

The observation data base on table 6 indicates that the current space utilization at DNB's TRX office falls short of national ergonomic and comfort guidelines. Employees are allocated less desk and floor space than recommended, and the lack of privacy elements (e.g., partitions, zoning) may contribute to discomfort or reduced satisfaction. These observations support the survey findings, where some respondents indicated dissatisfaction related to crowding, lack of privacy, or workspace limitations. This qualitative data reinforces the relationship between space utilization and occupant satisfaction, validating the second research objective and justifying the need for improved space planning and layout design.

4.4 Recommendation of Best Practices for Balancing Space Utilization and Occupant Satisfaction Analysis

Table 7: Recommendation of Best Practices for Balancing Space Utilization and Occupant Satisfaction

Frequencies Analysis				
Recommendation	Frequency	Percent	Valid Percent	Cumulative Percent
Option 1: Design for wellness and comfort like incorporate ergonomic furniture, sufficient lighting, thermal comfort, greenery, and access to quiet spaces to improve both satisfaction and productivity while ensuring efficient space usage.	7	6.9	6.9	6.9
Option 2: Enhance privacy through zoning by create distinct zones for quiet work, collaboration, and social interaction using partitions, acoustic panels, or spatial separation. This respects employee preferences and improves satisfaction.	30	29.4	29.4	36.3
Option 3: Maintain optimal occupancy levels to avoid overcrowding by monitoring space demand and ensuring that occupancy density aligns with comfort standards. Use hot-desking policies with real-time booking systems to reduce unused space and congestion.	14	13.7	13.7	50.0

Option 4: Regular feedback and satisfaction surveys by conduct periodic occupant surveys to gather feedback on space usage and satisfaction levels. Use this input to identify trends and implement responsive changes	39	38.2	38.2	88.2
Option 5: To implement flexible workspace design adopt modular furniture and adaptable layouts that can support both individual focus work and team collaboration. This maximizes spatial efficiency while accommodating diverse working styles.	12	11.8	11.8	100.0
Total	102	100.0	100.0	

Based on the table 7 best practices identified, the most recommended approach is Option 1: Conducting regular feedback and satisfaction surveys (38.2%), indicating that periodic occupant input is essential in improving space utilization. Option 2: Enhancing privacy through zoning (29.4%) is also considered effective, as it supports different work modes and improves user comfort. Although Option 3: Maintaining optimal occupancy levels (13.7%) showed no significant correlation in the study, it remains a practical strategy to avoid overcrowding. Option 5: Implementing flexible workspace design (11.8%) strongly aligns with the study's finding that layout flexibility has a very strong positive relationship with space utilization. Lastly, Option 1: Designing for wellness and comfort (6.9%) is seen as a supportive measure to enhance the overall working environment, indirectly contributing to better space usage.

5.0 CONCLUSION

In terms of practical implications, this research highlights the crucial role of workplace design in shaping space utilization and occupant satisfaction. Facility managers, designers, and organizational leaders should collaborate to create work environments that prioritize flexibility, comfort, and employee well-being. This includes implementing adaptable layouts, modular furniture, and zoning strategies that cater to diverse work styles and privacy needs. Regular feedback mechanisms should also be established to ensure that workplace design evolves in response to employee input. Moving forward, future research should further explore the impact of specific design elements on employee productivity and satisfaction, particularly in open plan office environments. Longitudinal studies could provide deeper insight into how changes in layout and space planning affect organizational efficiency over time. Additionally, research should consider how cultural, organizational, and job-specific factors influence employees' space needs and preferences. By advancing our understanding of these relationships, this research can inform evidence-based facility management strategies that support both operational performance and the holistic well-being of occupants.

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The Study of Employee Satisfaction Towards Workspace in Facilities Management Office

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ABSTRACT

This study investigates employee satisfaction with the workspace environment in a facilities management office, with the aim of enhancing overall workplace experience and efficiency. This research addresses the insufficient focus on workstation circumstances, which may significantly impact employee productivity, comfort, and overall job satisfaction. The study focuses on three main objectives: identifying the factors that influence workspace satisfaction, evaluating the current satisfaction levels among facilities management employees, and proposing strategies to enhance the workspace based on employee needs. A quantitative research methodology was employed, utilising a structured questionnaire comprising closed-ended questions. The survey was distributed to 111 participants engaged in the facilities management office. The research focused on four factors that affect employee satisfaction: layout and design, ergonomics and comfort, indoor environmental quality, and workspace flexibility and functionality. The findings indicate that all evaluated components demonstrated moderate employee satisfaction, with flexibility and functionality identified as the most significant factors contributing to this satisfaction. This emphasizes the need to prioritize flexible workspace attributes and ergonomic improvements to create a more supportive and productive work environment. The study proposes practical techniques for enhancing the workspace based on employee requirements and preferences. The results are expected to guide facility managers in creating more effective and employee-centric work environments.

*Keywords: e*mployee, satisfaction, workspace, facilities, management

1.0 INTRODUCTION

1.1 Research Background

Other issues are associated with technical solutions, such as insufficient room for working or storing, issues with mobile technology, or a lack of privacy. Problems are frequently reported as being accompanied by difficulties in attention, interruptions, and speech noise that is considered unimportant (Fieldson & Sodagar, 2020). Inefficient space utilisation is a widespread issue in modern offices. Studies have shown that many offices have occupancy rates far below their capacity, with as much as 30% of space being underused on a typical day. This inefficiency leads to increased operational costs as organisations continue to maintain unused areas. Furthermore, overcrowded regions can contribute to poor work conditions, which decrease employee satisfaction and reduce productivity (Holston-Okae & Mushi, 2021). It appears that employees are more content when working in single-room offices or in offices adjacent to multi-space offices. The most dissatisfied employees are those who work in small, medium, or large open space offices. According to research by Attaianese & Duca, (2012) employees who work in large open-plan offices take a greater number of sick days than those who work in smaller offices.

1.2 Aim & Research Objectives

The research aims to enhance employee satisfaction with the workspace in the facility management office, focusing on three main objectives: identifying the factors that influence workspace satisfaction, evaluating the current satisfaction levels among facility management employees, and proposing strategies to enhance the workspace based on employee needs.

2.0 LITERATURE REVIEW

Challenges included a perceived lack of control over the temperature, insufficient space, and other associated problems of densely populated offices. Being near a window decreased the likelihood of dissatisfaction and there was a clear relationship between self-perceived performance and satisfaction with the indoor environment. (Deswal et al., 2021). Room size plays a crucial role in determining the functionality and comfort of office spaces. The study revealed that rooms that are either undersized or oversized can negatively impact productivity. Correctly scaled spaces ensure efficient usage, reduce overcrowding, and improve overall employee comfort. Flexible room designs that adapt to varying needs, such as collaborative work, focused tasks, or meetings, are particularly effective in enhancing productivity (Parkinson et al., 2023).

Staff satisfaction in office spaces is a critical indicator of how well an office environment aligns with employees' needs and expectations, directly influencing their morale, productivity, and retention (Tomovska-Misoska et al., 2014).A workspace that fosters satisfaction typically includes sufficient personal space, comfortable ergonomic setups, and favourable environmental conditions, contributing to enhanced performance and well-being. However, multiple issues can arise that detract from this satisfaction. Office discomfort may arise from brightness, noisy machinery, drafts, or odours (Lusa et al., 2019). Although little lighting typically does not make vision impossible, the signals transmitted from the eyes to the brain may lead to interpretative difficulties. Inadequate lighting might result in impaired concentration and diminished work performance (Attaianese & Duca, 2022). Furthermore, the lack of ergonomically designed furniture and tools, such as adjustable desks and chairs, can lead to physical discomfort and long-term health issues, including back pain and repetitive strain injuries. These ergonomic deficiencies reduce focus and satisfaction, as employees may struggle to maintain comfort during extended work hours (Aboulfotouh et al., 2022).

3.0 METHODOLOGY

The study employs a quantitative research design. Quantitative research involves the gathering and examination of numerical data to identify patterns, correlations, and trends. This strategy is suitable for research intended to quantify variables and analyse correlations systematically and objectively. A stratified random sample method was utilised to guarantee proper representation of diverse groupings within the population. A sample of 90 respondents was selected from a population of 135 employees in the Facilities Management Office, utilising Krejcie and Morgan's sample size determination table. A structured questionnaire served as the principal instrument for data collection, sent to the chosen respondents. The study employed the Statistical Package for the Social Sciences (SPSS) software to analyse the acquired data efficiently and accurately. SPSS facilitated the researcher in processing extensive data sets, doing statistical analyses, and producing results that support reasonable conclusions about employee satisfaction with the workspace.

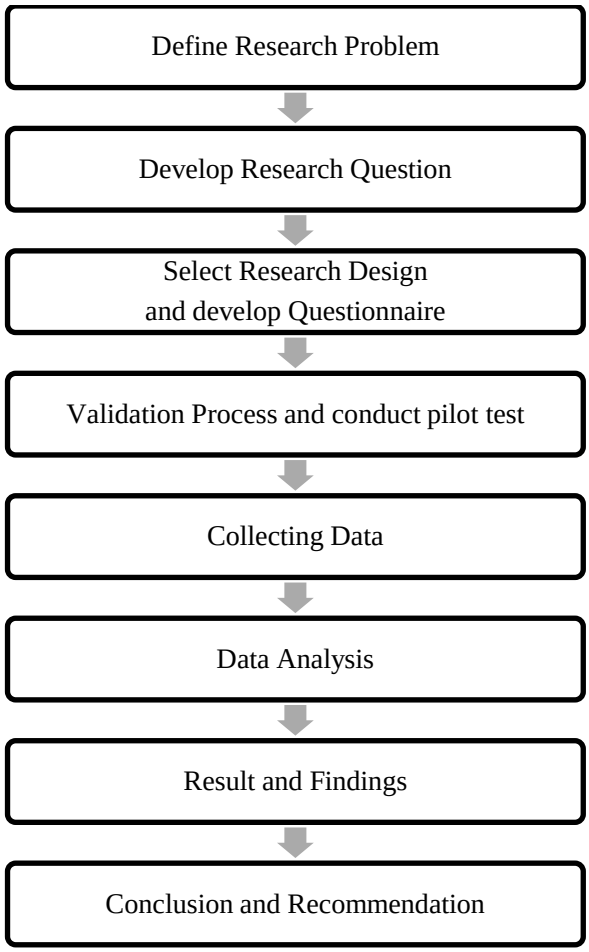

Figure 1: Flow chart of methodology process

This study followed a systematic methodology, starting with the identification of the research issue and the formulation of research questions. A quantitative study design was employed, and a questionnaire was developed and validated through a pilot test. Data was subsequently gathered from 90 participants utilising stratified random selection. The collected data was analysed with SPSS to identify trends associated with employee satisfaction regarding the workspace. The results were analysed, and conclusions and recommendations were formulated based on the findings.

Table 1: Reliability Coefficients Pilot Test for Each Variable

Variables	**No. of Items**	**Item Deleted**	**Cronbach's Alpha**
Layout and Design	5	-	0.714
Ergonomic and Comfort	5	-	0.850
Indoor Environment Quality	5	-	0.838
Flexibility and Functionality	5	-	0.776

The reliability test for the pilot study employed Cronbach's Alpha to evaluate the internal coherence of each variable in the questionnaire. Each variable comprised five items, and no items were eliminated during the testing procedure. The findings indicated that all variables

reached an acceptable to high level of reliability, as evidenced by Cronbach's Alpha values exceeding the required threshold of 0.7. Layout and Design achieved a score of 0.714, Ergonomic and Comfort attained 0.850, Indoor Environment Quality obtained 0.838, and Flexibility and Functionality obtained 0.776. The results demonstrate that the questionnaire items are consistent and reliable for implementation in the data gathering phase.

4.0 RESULTS AND DISCUSSION

The demographic profile of the respondents contains their personal information and questions related to their behaviour. The questions that are related to the respondents' behaviour are intended to assess their ability to recall the information (Amit Prasad, 2022). This study also requested the respondents' personal information, including their job position, work experience, and the number of hours spent at the office.

Table 2: Respondent's demographic profile

		Frequency	Percentage (%)
Job Position	Facilities Manager	6	5.4
	Head of Department	19	17.1
	Engineer	26	23.4
	Junior Engineer	35	31.5
	Administrative Staff	25	22.5
Working Experience	1-4 Years	43	38.7
	5-9 Years	37	33.3
	Less than 1 Years	13	11.7
	More than 1 Years	18	16.2
Working Hours	5 to 8 hours	63	55.9
	Less than 5 hours	16	14.4
	More than 8 hours	32	28.8

This study aimed to evaluate employee satisfaction with their workspace in the facilities management office, focusing on four key variables: layout and design, ergonomics and comfort, indoor environmental quality, and flexibility and functionality. A structured questionnaire was distributed to 135 respondents, and responses were measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Descriptive statistics were also calculated for each item and variable to investigate their levels among the respondents. The three levels of categories according to the mean consist of low (1.00 – 2.33), medium (2.34 - 3.67), and high (3.68 – 5.00) (Pohan & Angkat, 2022)

Table 3: Descriptive statistics for variables

Descriptive Statistic				
	N	Mean	Std. Deviation	Level
Layout & Design	111	3.103	0.549	Medium
Ergonomics & Comfort	111	3.041	0.638	Medium
Indoor Environment Quality	111	3.139	0.724	Medium
Flexibility and Functionality	111	3.072	0.694	Medium

Table 4: Descriptive analysis for variable 1

Layout & Design	**Mean**	**SD**	**Level**
1. The size of my workstation/desk is suitable for my work needs.	2.937	1.073	Medium
2. The arrangement of furniture supports my work activities effectively.	3.045	1.099	Medium
3. The workspace layout allows for efficient movement and accessibility.	3.279	1.200	Medium
4. The office layout supports teamwork and collaboration.	3.180	1.122	Medium
5. The workspace is free from clutter and well-organised.	3.072	1.085	Medium

Table 4 shows the descriptive statistics for the layout and design variable. Overall, the layout and design of the workspace are rated at a medium level (Mean = 3.103). The item with the highest level of layout and design is the item on "The workspace layout allows for efficient movement and accessibility" (Mean=3.279) showing a higher degree of satisfaction with accessibility and mobility within the workspace and the lowest level item is "The size of my workstation/desk is suitable for my work needs" (Mean=2.937) indicating something of a lower yet moderate level of satisfaction. This shows that although several employees consider their workstations sufficient, others believe the workstation dimensions may not fully meet their requirements. Other than that, the arrangement of furniture to facilitate work activities is also within the medium range (Mean = 3.045), indicating a potential for enhancing workflow efficiency through improved furniture positioning. The medium score for office layout supporting collaboration (Mean = 3.180) suggests that there is potential to improve collaborative design features, despite the office layout promoting teamwork among the teams. The workspace organisation achieved a mean score of 3.072, categorising it as medium. This suggests that while the workspace is primarily organised, messiness is still as concerned.

Table 5: Descriptive analysis for variable 2

Ergonomics & Comfort	Mean	SD	Level
1. The workstation's height and adjustability meet my needs.	2.982	1.191	Medium
2. The office setup promotes good posture and physical well being.	3.198	1.099	Medium
3. I have enough personal space to work comfortably	3.045	1.200	Medium
4. The workspace is designed to reduce physical strain and fatigue.	3.054	1.122	Medium
5. The workspace is flexible enough to accommodate my work needs (e.g., standing desks, adjustable lighting, flexible seating)	2.928	1.085	Medium

Table 5 shows the descriptive statistics for the ergonomics and comfort variables. The aspect of Ergonomics and Comfort was analyzed through five questions to determine whether the workstation facilitates employee well-being and comfort. All items produced moderate satisfaction levels (Mean=3.041), as indicated by their average scores. The item that highest level of ergonomics and comfort is item on the "The office setup promotes good posture and physical well being." (Mean=3.198) this indicates a relatively higher valuation of office ergonomics, suggesting that the existing arrangement adequately facilitates healthy working postures for the majority of employees and lowest level item on "The workspace is flexible enough to accommodate my work needs (e.g., standing desks, adjustable lighting, flexible seating) " (Mean=2.928) this indicates that although some flexibility is present, additional adaptive components are need to accommodate diverse and changing work styles. The statement "The workstation's height and adjustability meet my needs" received a mean score of 2.982. This indicates moderate satisfaction, with potential enhancements required to offer further ergonomic adjustability options that accommodate diverse body types and work preferences. The statement "I have sufficient personal space to work comfortably" received a mean score of 3.045, indicating moderate satisfaction. Although numerous employees consider their workstations sufficient, certain areas may encounter overcrowding or spatial constraints. The workspace's effectiveness in reducing physical strain received a score of 3.054, suggesting that ergonomic improvements are moderately effective. Nonetheless, additional ergonomic improvements, such as superior seating or increased mobility options, may elevate satisfaction levels.

Table 6: Descriptive analysis for variable 3

Indoor Environment Quality	Mean	SD	Level
1. The office lighting is sufficient and comfortable for working.	3.243	1.154	Medium
2. The ventilation and air quality in the office are adequate.	3.117	1.299	Medium
3. The noise level in the office is at an acceptable level for focused work.	3.180	1.097	Medium
4. The office temperature remains comfortable throughout the day.	3.117	1.234	Medium

5. There are sufficient natural elements (e.g., windows, plants) to create a comfortable workspace.	3.036	1.119	Medium

Table 6 shows the descriptive statistics for the indoor environment quality variable. Overall, the indoor environment quality for the workspace is at a medium level (Mean=3.129). The item that highest level of indoor environment quality is item on the “The office lighting is sufficient and comfortable for working ” (Mean=3.243) this indicates that the majority of employees consider the lighting sufficient for daily tasks in the office and lowest level item on "There are sufficient natural elements (e.g., windows, plants) to create a comfortable workspace." (Mean=3.036) this indicates a possible opportunity for improvement through biophilic design, such the incorporation of plants, enhancing external views, or increasing access to natural light. The statement, "The ventilation and air quality in the office are adequate," had a mean score of 3.117, suggesting that while the air quality is satisfactory, there is potential for improvements to enhance comfort. The average score for "The noise level in the office is at an acceptable level for focused work" was 3.180, indicating that the work environment is generally favourable for concentration. However, it may not be optimal for all individuals. The statement "The office temperature remains comfortable throughout the day" received a mean score of 3.117, indicating moderate satisfaction with the thermal environment at the workplace.

Table 7: Descriptive analysis for variable 4

Flexibility and Functionality	**Mean**	**SD**	**Level**
1. The workspace is adaptable to different tasks (e.g., focused work, meetings, collaboration).	3.207	1.184	Medium
2. I can personalize my workspace to improve my comfort and productivity.	2.910	1.116	Medium
3. The office has sufficient break areas or relaxation spaces.	2.973	1.304	Medium
4. The meeting rooms and common areas are well-equipped and accessible.	2.991	1.187	Medium
5. Essential office facilities (printers, meeting rooms, pantry, restrooms, etc.) are easily accessible from my workspace.	3.279	1.121	Medium

Table 7 shows the descriptive statistics for the flexibility and functionality variable. Overall, the flexibility and functionality of the workspace are at a medium level (Mean = 3.17). The item with the highest level of flexibility and functionality is the item on "Essential office facilities (printers, meeting rooms, pantry, restrooms, etc.) are easily accessible from my workspace." (Mean=3.279), and the second highest level item is on "The workspace is adaptable to different tasks (e.g., focused work, meetings, collaboration)." (Mean=3.207) this indicates that the majority of employees acknowledge a moderate degree of adaptability in their work environment, facilitating diverse work activities. Other items, such as the ability to personalize the workspace (mean = 2.910), the availability of relaxation or break areas (mean = 2.973), and the accessibility and equipment of meeting rooms (mean = 2.991), all received medium ratings. The results indicate that although fundamental functioning requirements are

satisfied, there remains potential for enhancement, particularly in providing further personalisation options and improving relaxation or informal areas.

5.0 CONCLUSION

In summary, employees emphasise the importance of efficient layouts, optimal indoor environments, well-maintained facilities, and wellness support. Improving these areas will significantly increase employee satisfaction, leading to enhanced productivity and a more conducive work environment. This research offers valuable insights into facility management by identifying specific workspace elements that have a significant impact on employee satisfaction. It underscores the significance of incorporating employee feedback into design and maintenance decisions, which can assist facility managers, designers, and organisational leaders in creating more adaptive and human-centred work environments. From a futuristic perspective, as technology advances and work methodologies evolve, future workspace designs may incorporate digital monitoring systems that autonomously regulate lighting, temperature, and noise levels according to individual preferences. Moreover, it offers statistical data that can inform policy development and workplace optimisation efforts in both the public and private sectors.

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User Satisfaction Towards Landscape Services in Campus Open Space

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ABSTRACT

This study aims to propose strategies for improving landscape services in campus open space towards landscape maintenance, health and well-being and landscape sustainability in campus university open space. The primary objectives are to identify the factors influencing user satisfaction, analyze current satisfaction levels, and recommend improvements based on user feedback. The issue addressed in this research is the disconnect between campus landscape design and user expectations. Many open spaces lack essential natural features, functional amenities, and proper maintenance, leading to underutilization and dissatisfaction. These shortcomings may negatively impact student well-being and the institution's sustainability goals. A quantitative research methodology was employed, utilizing stratified random sampling with 322 student respondents from both faculty. Data was collected through structured online questionnaires and analyzed using SPSS software, employing descriptive statistics, frequency distributions, mean scores, and Cronbach's Alpha reliability tests, to determine the key predictors of satisfaction. Findings revealed high satisfaction levels across all variables, with mean scores exceeding 4.4, where Landscape Sustainability achieved the highest rating (4.5000), followed by Landscape Maintenance (4.4640) and Health and Well-being (4.4267), with users particularly appreciating eco-friendly design elements, plant upkeep, green spaces for stress reduction, and shaded areas. The study concludes that well-maintained, environmentally conscious landscapes significantly enhance campus life and support sustainable practices, recommending continued maintenance focus, user feedback integration, and green infrastructure expansion.

Keywords: satisfaction, landscape, services, campus, space

1.0 INTRODUCTION

1.1 Research Background

Tudorie et al. (2020) emphasize that well-maintained campus landscapes featuring diverse vegetation, natural shade, and water elements significantly enhance user satisfaction and the university's image, highlighting the importance of assessing landscape services to support campus sustainability. Ishak et al. (2021) note that campus landscaping plays a vital role not only in aesthetics but also in promoting student well-being, stress management, and social interaction, underlining the need to evaluate both the current landscape condition and students' landscape needs. Meanwhile, Mogra and Furlan (2017), in their study at Qatar University, reveal that climate and spatial design influence students' use of green spaces, particularly in the summer, and stress the necessity for revitalizing outdoor green areas to improve usability and comfort.

1.2 Aim & Research Objectives

This study aims to propose strategic improvements to landscape services in campus open spaces, focusing on enhancing maintenance practices, promoting user health and well-being, and ensuring landscape sustainability. To achieve this, the research seeks to identify the key factors that influence user satisfaction with campus landscapes, analyze users' perceptions and levels of satisfaction regarding the quality of existing landscape services, and ultimately provide practical recommendations based on user feedback. These recommendations are intended to

guide better landscape planning and management practices that align with the sustainable development goals of higher education institutions.

2.0 LITERATURE REVIEW

2.1 Landscape Services in Campus Open Space

According to Tudorie et al. (2020), the design of Campus Open Spaces (COS) should be guided by sustainability criteria, as high-quality open spaces contribute to the development of semi-natural ecosystems and learning environments. Vallés-Planells et al. (2016) emphasize that COS support social interaction, which strengthens formal learning through informal idea exchange. Lau et al. (2014) state that COS function as urban ecosystems that integrate green and grey elements, offering landscape services shaped by the campus community. Carney (2000) highlights the importance of spaces that encourage social interaction to reduce student stress, while Neuman (2003) points out that a well-designed campus landscape enhances campus image and positively impacts students' quality of life. Felsten (2009) also affirms that campus landscapes play a key role in supporting students' daily routines that require continuous focus and concentration.

2.2 Landscape Maintenance

According to Mohammad (1995), the sustainability and aesthetic value of recreational forests heavily depend on effective landscape maintenance, which not only enhances user experience but also reduces environmental damage. Kher (2012) stresses that poor upkeep such as uncollected litter or damaged trees can negatively affect public perception and the park's reputation. Sternloff and Warren (1977) emphasize that maintenance should follow the highest standards and best management practices, yet many recreational forests still face issues due to weak planning and lack of clear management strategies (Reeves, 2000; Osman et al., 2006). Visitor perception plays a crucial role in identifying maintenance shortcomings and guiding improvements (Kher et al., 2009; Deng, 2007). As Dorwart (2004) notes, user feedback can help set quality benchmarks and maintenance priorities, while Elmendorf et al. (2005) affirm that visitors consistently value clean, well-maintained environments. A positive perception, like that observed in the Great Smoky Mountain National Park due to its good upkeep, highlights how well-managed landscapes reflect the effectiveness of park management (Nassauer, 1997; Dorwart, 2007; Gobster, 1995).

2.3 Health and Well-Being

According to Dooris et al. (1998), many educational institutions have embraced a socioecological view of health, recognizing the interplay between personal and environmental factors in shaping well-being. Academic greenspaces play a vital role in this regard, positively impacting students' physical, mental, and social well-being (Felsten, 2009; Windhorst & Williams, 2015; Abraham et al., 2010). Greenspaces also enhance social interaction and a sense of belonging, contributing to social cohesion and identity (Leyden, 2003; WHO, 2016). Matsuoka (2010) and Wallner et al. (2018) found that access to nature correlates with improved academic performance and cognitive recovery. Landscape is perceived both physically and emotionally, shaped by sensory experiences and personal meanings such as memory, attachment, and identity (Kaplan & Kaplan, 1989; Davenport & Anderson, 2005). Moreover, high-quality green environments encourage social connection, psychological growth, and a sense of safety, all of which are essential for community well being (Vries et al., 2013; Bertram & Rehdanz, 2015; Chee, 2016).

2.4 Landscape Sustainability

According to Wu (2019), geographers and ecologists have advanced sustainability science through landscape-based and land-based approaches, emphasizing concepts such as landscape multifunctionality, resilience, and sustainable land management. Landscape sustainability refers to the ability of a resilient, multifunctional landscape to continually deliver ecosystem services vital for human well-being amid environmental changes (Lovell & Johnston, 2009; Musacchio, 2009; Cumming, 2011). While Potschin and Haines-Young (2006) argue that various landscape configurations can be considered sustainable if they maintain goods and services, Blaschke (2006) emphasizes that spatial pattern and landscape structure are equally crucial as they influence ecological processes and meaning. Forman (1995) highlights the need to understand whether there is an optimal or adequate spatial arrangement of landscape elements in multifunctional settings. Ultimately, sustainability planning should focus on identifying landscape options that maintain valued ecosystem outputs rather than seeking ideal forms (Opdam et al., 2006). Moreover, green spaces are increasingly valued as essential urban assets for mitigating climate change and enhancing environmental quality (Jim & Chen, 2010; APHA, 2013; Shukri, 2011). Figure 1 shows the conceptual framework in this study.

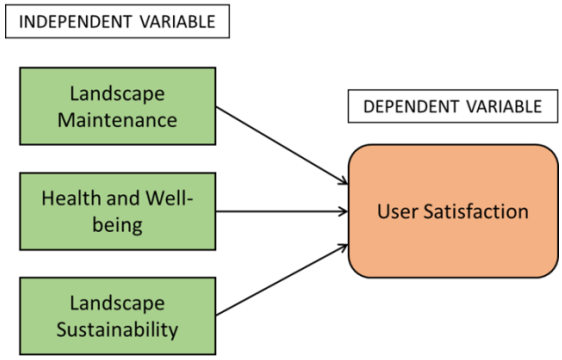

Figure 1: Conceptual Framework

3.0 METHODOLOGY

The methodology of this study employed a quantitative research approach, specifically using a survey method to collect empirical data from respondents. The core research instrument was a structured questionnaire divided into three key sections, Section A gathered demographic data such as gender, age, education level, and campus location, Section B assessed user satisfaction with landscape services using a 5 point Likert-scale items across three domains landscape maintenance, health and well-being, and landscape sustainability, while Section C comprised open-ended questions for respondents to suggest improvements. This instrument was designed to ensure comprehensive and measurable insights into user experiences with campus open spaces.

A stratified random sampling technique was adopted to ensure balanced representation from two main strata students from UiTM Puncak Alam and UiTM Shah Alam, both from the Faculty of Alam Bina. A total of 322 respondents participated, making the sample robust and statistically reliable. For data analysis, SPSS software was used to perform both descriptive and inferential analyses, including frequency distributions, mean scores, and reliability tests such as Cronbach's Alpha. These techniques ensured that the data interpretation was valid, reliable, and capable of informing practical recommendations for landscape service improvements.

4.0 RESULTS AND DISCUSSION

4.1 Tables and Figures

The descriptive statistics were meticulously calculated for each item and variable to thoroughly examine their levels among the respondents. According to Mohd Najib Abd Ghafar (2003), the categories based on mean values are divided into three levels: low (1.00 – 2.33), medium (2.34 - 3.67), and high (3.68 – 5.00).

Table 1: Descriptive Statistics for Landscape Maintenance (N=322, Mean=4.4640)

Items	Mean	SD	Level
Landscape Maintenance			
B11. How satisfied are you with the cleanliness of the campus open spaces?	4.47	0.553	High
B12. How satisfied are you with the condition of the pathways and walkways in the campus open spaces?	4.44	0.562	High
B13. How satisfied are you with the general maintenance of seating areas and benches in the campus open spaces?	4.44	0.635	High
B14. How satisfied are you with the upkeep of plants, trees, and flower beds in the open spaces?	4.52	0.575	High
B15. How satisfied are you with the overall appearance of the landscape maintenance in campus open spaces?	4.44	0.635	High

Table 1, the five items under Landscape Maintenance all scored within the high range, with an overall mean of 4.4640. Respondents expressed strong satisfaction with the cleanliness, condition of pathways, and maintenance of seating areas, plant care, and overall appearance of the campus landscape. The item with the highest mean was plant and flower bed upkeep (4.52), underscoring the importance of natural elements in enhancing user satisfaction and campus aesthetics.

Table 2 Descriptive Statistics for Health and Well-Being (N=322, Mean=4.4267)

Items	Mean	SD	Level
Health and Well-Being			
B21. How satisfied are you with the aesthetic appeal of the campus open spaces in relation to improving mental well-being?	4.34	0.781	High
B22. How satisfied are you with outdoor exercise facilities such as exercise equipment or jogging paths in the campus open spaces?	4.29	0.843	High
B23. How satisfied are you with the overall air quality in the campus open spaces?	4.46	0.651	High

B24. How satisfied are you with the presence of green spaces that promote relaxation and stress reduction?	4.53	0.541	High
B25. How satisfied are you with the availability of shaded areas in the campus open spaces?	4.52	0.548	High

Table 2 shows that the Health and Well-Being dimension also received high ratings, with an overall mean of 4.4267. Respondents reported high satisfaction with aspects such as aesthetic appeal (4.34), outdoor facilities (4.29), air quality (4.46), presence of green spaces for stress relief (4.53), and availability of shaded areas (4.52). These results highlight the role of campus landscapes in promoting mental and physical well-being.

Table 3 Descriptive Statistics for Landscape Sustainability (N=322, Mean=4.5000)

Items	Mean	SD	Level
Landscape Sustainability			
B31. How satisfied are you with the incorporation of eco-friendly and sustainable element in the landscape design?	4.60	0.516	High
B32. How satisfied are you with efforts to minimize waste and promote recycling in landscape management?	4.47	0.622	High
B33. How satisfied are you with the campus's efforts in reducing carbon footprints through landscaping choices?	4.29	0.847	High
B34. How satisfied are you with the preservation of open green spaces for ecological balance?	4.57	0.544	High
B35. How satisfied are you with the presence of recycling bins in the landscape areas?	4.58	0.548	High

Table 3 presents the highest overall mean of 4.5000 for the Landscape Sustainability variable. Respondents strongly acknowledged the importance of eco-friendly designs, recycling efforts, carbon footprint reduction, green space preservation, and provision of recycling bins. The highest-rated item was the incorporation of sustainable landscape design elements (4.60), reflecting a strong appreciation for environmental sustainability initiatives within campus landscapes.

Table 4: Mean For Each Variables (N=322)

Variables	Mean
Landscape Maintenance	4.4640
Health and Well-Being	4.4267
Landscape Sustainability	4.5000

Based on Table 4, the average mean scores were calculated for three main variables: Landscape Maintenance, Health and Well-Being, and Landscape Sustainability, based on a sample of 322 respondents. The results indicate that all three variables received high levels of satisfaction, with mean scores exceeding 4.4.

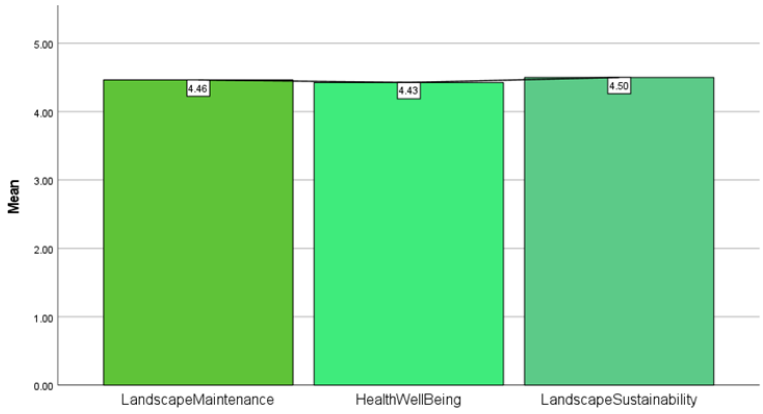

Figure 2: Graph Mean for Variable (N=322)

The graph in figure 2 shows the results consistently high satisfaction levels across all three variables, with Landscape Sustainability being the most appreciated, followed closely by Landscape Maintenance and Health and Well-Being.

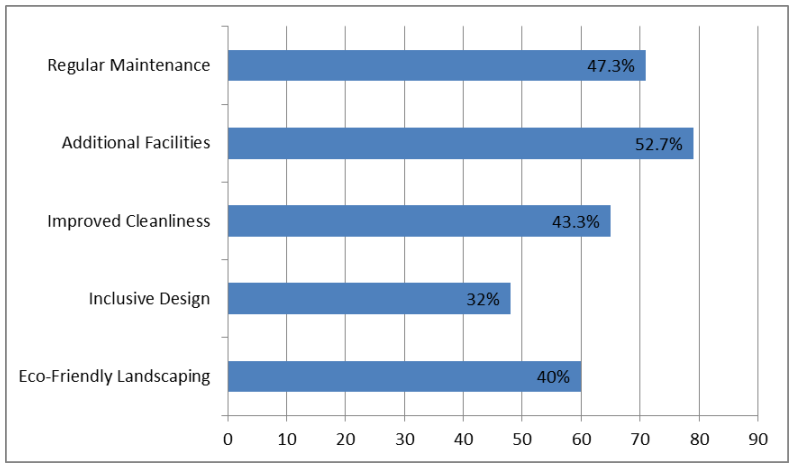

Figure 3: Graph Recommendation Respondents

The graph in figure 3 shows the results for objective 3, the data was analysed using percentages to identify the most effective recommendations for improving landscape services in the campus open space, it was found that the majority of respondents 52.7% supported the addition of facilities such as benches and gazebos to improve student comfort. This indicates a high need for comfortable and user-friendly rest areas. Periodic maintenance proposals such as tree, lawn and garden maintenance plans recorded 47.3%, indicating the importance of continuous care aspects in maintaining landscape quality. Next, 43.3% supported improving cleanliness through the placement of recycling bins in strategic locations, reflecting awareness of sustainability and waste management. Eco-friendly landscaping proposals such as smart irrigation systems received 40% support, indicating interest in the use of green technology. However, proposals for inclusive design that is OKU-friendly only received 32%, indicating that the accessibility aspect is still receiving less attention and requires more awareness and further action. Overall, the results reveal that users prioritize fundamental aspects like maintenance and cleanliness, while still showing growing awareness of accessibility and environmental sustainability.

5.0 CONCLUSION

This study indicate that users of campus open spaces at Faculty Alam Bina at UiTM Puncak Alam and Faculty Alam Bina at UiTM Shah Alam are highly satisfied with landscape maintenance, health and well-being, and landscape sustainability, with all variables scoring above 4.4 on average. This suggests that well-maintained and environmentally conscious landscapes play a crucial role in enhancing campus life, supporting mental and physical health, and reinforcing sustainable practices. The strong satisfaction with elements such as green space upkeep, shaded areas, and eco-friendly infrastructure highlights the importance of user-centred and sustainable landscape planning. These insights imply that future efforts should focus on continuous maintenance, user feedback integration, and the expansion of green infrastructure. Future research could explore longitudinal impacts, comparative analysis across campuses, qualitative insights into user perceptions, and behavioural studies to further understand usage patterns and inform more strategic landscape development.

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Vendor Relationship Management in Facilities Procurement

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ABSTRACT

Vendor Relationship Management (VRM) plays a critical role in facilities procurement, ensuring the seamless acquisition of goods and services while fostering long-term partnerships. This study explores the strategies and practices of VRM, focusing on its impact on procurement efficiency, cost optimization, and service quality within facility management. It examines the key components of VRM, including vendor selection, performance evaluation, communication, and relationship sustainability. By analyzing case studies and industry best practices, the research highlights how effective vendor relationships can mitigate risks, improve compliance, and drive innovation. This study aims to explore and evaluate the impact of Vendor Relationship Management (VRM) on procurement strategies in enhancing operational efficiency, cost-effectiveness, and fostering long-term business partnerships in competitive industries. The research also propose the best strategy to improve the effectiveness of vendor relationship management in the facilities procurement. A qualitative approach was adopted, utilizing a structured question that include nine question to give to participant. The participants included workers from UDA HQ procurement teams, NPRA engineering department and Radicare facilities management. The findings provide actionable insights for facility managers and procurement professionals to develop robust vendor management frameworks, ultimately enhancing organizational outcomes in a competitive marketplace.

Keywords: vendor, relationship, management, facilities, procurement

1.0 INTRODUCTION

1.1 Research Background

Recent research has emphasized the need for fostering collaborative relationships between vendors and procurement teams to improve operational efficiency and reduce risks in the supply chain. According to Luzzini and Ronchi (2021), building strategic partnerships through vendor relationship management (VRM) allows companies to leverage supplier capabilities, foster innovation, and create competitive advantages. By enhancing communication and trust, organizations can secure long-term benefits such as Overview of VRM challenges specific to the facilities sector, including costs and quality concerns improved service quality and cost control. The advent of digital technologies has revolutionized procurement strategies, making vendor management more efficient and transparent. Montoya-Torres et al. (2021) highlight the integration of digital tools, such as blockchain and AI, in procurement processes to enhance data accuracy, track supplier performance, and mitigate risks. This shift not only improves decision-making but also strengthens the monitoring and management of vendor relationships.

1.2 Problem Statement

The increasing complexity of global supply chains has necessitated organizations to shift from traditional procurement approaches to more strategic frameworks such as Vendor Relationship Management (VRM). Despite the recognized importance of effective vendor relationships in

enhancing supply chain performance, many organizations struggle to develop coherent procurement strategies that leverage these relationships effectively (Cai et al., 2017). In today's fast-paced and competitive market, the effectiveness of Vendor Relationship Management (VRM) is crucial for organizations seeking to maximize value through procurement. However, many businesses face challenges in integrating VRM practices into their procurement strategies, resulting in a disconnection between supplier capabilities and organizational needs (Monczka et al., 2015). Inflation and rising costs have put significant pressure on procurement departments to optimize vendor contracts without sacrificing quality or damaging supplier relationships. Striking this balance between cost control and maintaining strong vendor ties has become a pressing issue in recent years (Gonzalez & Malhotra, 2022).

1.3 Aim & Research Objective

The aim of this research to explore the main factors that influence vendor relationship management in the earnings of facilities and identify the best strategies to improve this relationship.

To achieve the aim of this research and to address the research question, the following objective has been established:

a) To identify the challenges faced by organizations in managing vendor relationship management.

b) To analyze the effect of effective vendor relationship on the effectiveness of facility procurement.

c) To propose the strategy to improve the effectiveness of vendor relationship management in facilities procurement.

2.0 LITERATURE REVIEW

Building trust and fostering collaboration are fundamental to effective VRM. Open communication, transparency, and mutual respect are essential for establishing strong relationships with vendors (Handfield, R. M., & Nichols, E. L., 2018). Aligning the goals and objectives of both the organization and the vendor can create a sense of shared purpose and drive mutual success. Collaborative goal-setting and regular performance reviews can help ensure that both parties are working towards the same outcomes (Monczka, R. M., Handfield, R. B., Giunipero, L. C., & Patterson, J. L., 2015). Effective VRM requires careful management of power dynamics between the organization and its vendors. Building relationships based on mutual respect and collaboration can help mitigate potential conflicts (Handfield & Nichols, 2018). Sustainability is increasingly becoming a critical factor in vendor relationship management and procurement strategies. Huo, Zhao, and Lai (2021) argue that organizations are now integrating ethical and sustainable practices into their procurement policies to meet growing environmental and social expectations. These practices not only enhance corporate reputation but also ensure compliance with global standards and reduce the risk of supply chain disruptions.

2.1 Vendor

A **vendor** is an individual or business entity that supplies goods or services to another organization, playing a vital role in the procurement and supply chain ecosystem. Vendors can include manufacturers, wholesalers, service providers, and even online retailers, depending on the nature of the transaction and the industry involved. In facilities management, for example, vendors are often responsible for delivering maintenance services, equipment, or supplies essential to building operations. The relationship between a company and its vendors is usually governed by formal contracts that specify delivery timelines, pricing, performance standards, and compliance requirements. Effective vendor management not only ensures consistent product and service quality but also helps reduce costs, minimize risks, and build long-term partnerships. As highlighted by Indeed (2023), vendors are crucial business partners whose performance directly affects the success of procurement and operational strategies. Similarly, Taulia (2023) emphasizes that managing vendors efficiently is key to maintaining a resilient and responsive supply chain that can adapt to changing market conditions and customer demands.

2.2 Relationship

In the procurement and supply chain management, a **relationship** refers to the ongoing and strategic interaction between an organization and its suppliers or vendors, aimed at creating mutual value and achieving long-term objectives. Unlike purely transactional engagements, modern procurement practices emphasize collaborative relationships built on trust, performance transparency, and aligned goals. This approach is known as **Supplier Relationship Management (SRM)**, which involves classifying suppliers by their strategic importance and managing them accordingly to foster innovation, mitigate risks, and improve service delivery (TechTarget, 2024). Strong supplier relationships enable organizations to respond more effectively to market disruptions, enhance product or service quality, and reduce operational risks. According to Gartner (2024), firms that adopt structured relationship management practices report improved supply chain resilience and competitive advantage. Veridion (2024) further notes that over 75% of procurement leaders are now prioritizing supplier collaboration using digital tools such as AI and SRM software to monitor performance and drive efficiency. Therefore, cultivating robust supplier relationships is essential for sustainable procurement performance and organizational agility in today's dynamic business environment.

2.3 Management

In procurement and supply chain contexts, a **relationship** refers to the strategic and collaborative engagement between an organization and its suppliers, focused on achieving mutual goals such as cost efficiency, innovation, and service quality. Modern supplier relationships have shifted away from transactional exchanges toward long-term partnerships grounded in trust, transparency, and shared performance metrics. This approach, known as **Supplier Relationship Management (SRM)**, is a structured process where suppliers are evaluated and managed to optimize their value contributions to the organization. According to QAD (2024), organizations that implement SRM strategies benefit from enhanced supplier performance, reduced risks, and increased operational agility. Similarly, CoreX (2024) emphasizes that digital tools such as eProcurement platforms and supplier portals have significantly improved relationship transparency and efficiency, enabling stronger supplier collaboration. Wikipedia (2024) also notes that SRM facilitates innovation and competitive

advantage by aligning supplier capabilities with strategic business needs. Thus, effective supplier relationships are foundational to procurement success in today's dynamic business environment.

2.4 Facilities

Facilities refer to the physical assets, infrastructure, and services that support an organization's operations. Effective **Facilities Management (FM)** ensures these assets are maintained efficiently, aligning with organizational goals and adapting to evolving business needs. According to the Royal Institution of Chartered Surveyors (RICS), FM is "the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities" (RICS, 2023). This encompasses both hard services (e.g., HVAC, electrical systems) and soft services (e.g., cleaning, security). In 2023, CBRE highlighted that FM procurement leaders are focusing on strategies to mitigate risks associated with economic instability and inflation. Their survey revealed that organizations are actively addressing supply chain risks and navigating economic uncertainties by committing to innovation, sustainability, and workforce development (CBRE, 2023).

2.5 Procurement

Procurement is a strategic organizational function that involves sourcing, acquiring, and managing goods and services essential for an organization's operations. It encompasses activities such as identifying needs, selecting suppliers, negotiating contracts, and ensuring timely delivery. In 2021, the significance of procurement was underscored by global supply chain disruptions, prompting organizations to enhance their procurement strategies for greater resilience and efficiency. According to Caccialanza (2023), procurement is not merely about purchasing but involves a comprehensive process that aligns with an organization's strategic goals, ensuring sustainability and long-term value creation. This perspective highlights the evolving role of procurement in addressing broader organizational objectives beyond cost savings. Furthermore, a study by Chen and Li (2021) emphasizes the financial implications of optimized procurement strategies. Their research indicates that effective procurement practices contribute significantly to a firm's financial performance, underscoring the importance of strategic procurement in achieving organizational success. In summary, procurement in 2021 has evolved into a multifaceted function that plays a critical role in organizational strategy, financial performance, and resilience against supply chain disruptions.

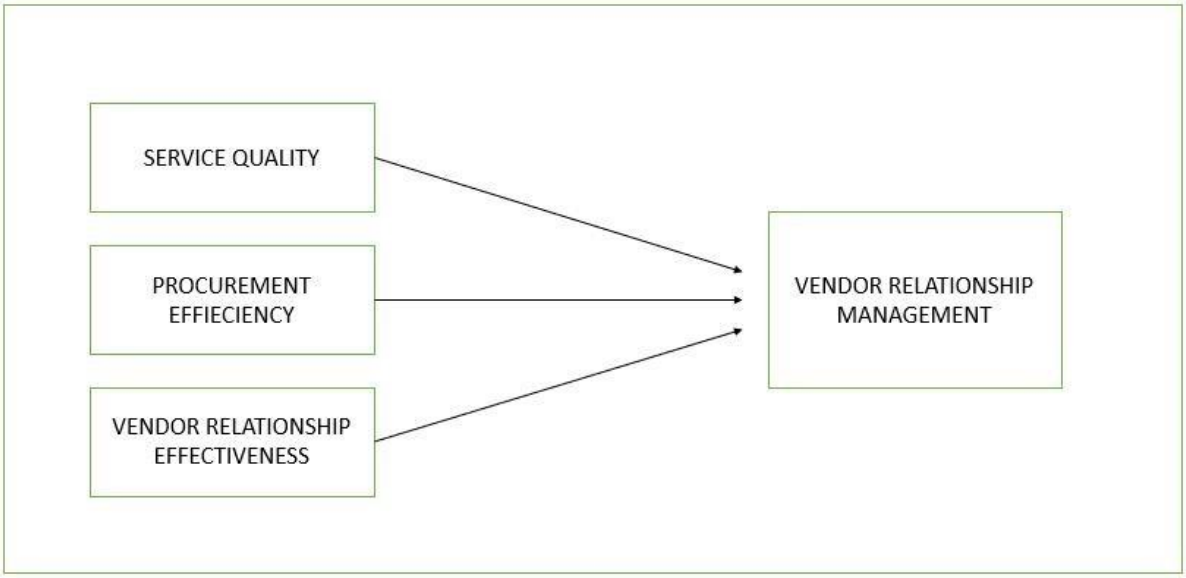

Figure 1: Conceptual Framework

3.0 METHODLOGY

This study use the data gathering procedure, which includes structured and semi-structured in order to ensure complying with the research's objectives. The study use to get data from eight participants in three places and various position. The list of question was created to provide in depth-insight and experience overview of the topic being studied. Furthermore, data analysis methodologies are provided, demonstrating how the acquired data would be handled methodically in order to identify patterns and trends. Bryman (2016) states that research methodology is "a set of principles and procedures used to conduct research, ensuring reliability, validity, and ethical considerations in data collection and analysis".

3.1 RESEARCH DESIGN

Research design refers to the overall strategy and plan that a researcher uses to integrate the different components of the study in a coherent and logical way, ensuring that the research problem is effectively addressed. It serves as the blueprint for the entire research process, guiding the collection, measurement, and analysis of data. Qualitative research design focuses on understanding the meaning and interpretation of social phenomena through in-depth exploration and analysis of non-numerical data (Creswell, 2018). It often involves an iterative process of data collection and analysis, where researchers engage in ongoing reflection and adjustment of their approach based on emerging insights.

3.1 RESEARCH INSTRUMENT

In qualitative research, a research instrument refers to the tools and techniques used to collect data that capture the depth, complexity, and meaning of participants' experiences. Unlike quantitative research, which relies on standardized instruments such as surveys and tests, qualitative research employs flexible and adaptive tools like interviews, focus groups, observations, and document analysis (Creswell & Poth, 2018). Semi-structured or unstructured interviews allow researchers to explore participants’ perspectives in depth, while observations

help capture behaviours and interactions in natural settings (Merriam & Tisdell, 2016). Additionally, focus groups enable discussions that reveal shared meanings, and document analysis provides insights from existing texts and records (Patton, 2015).

Qualitative research instruments are often open-ended, interactive, and evolving, allowing for deeper exploration of themes. To ensure credibility, researchers refine instruments through pilot testing, peer debriefing, and triangulation (Lincoln & Guba, 1985). A well-designed qualitative research instrument enhances the richness and validity of data, contributing to meaningful and insightful findings.

4.0 RESULT & DISSCUSSION

The findings reveal a strong alignment among all participants on the importance of implementing **clear Key Performance Indicators (KPIs), regular performance reviews, and effective communication** as the cornerstone strategies in vendor relationship management. These strategies are fundamental for aligning expectations and ensuring consistent vendor output. The integration of **Service Level Agreements (SLAs)** and vendor scorecards were also widely practiced to monitor performance and guide decision-making. Participants from UDA HQ notably emphasized the use of KPIs and periodic reviews to establish transparency and accountability, while NPRA highlighted the value of early vendor involvement in planning processes to enhance operational alignment.

Theme	Frequency
Clear KPIs & SLAs	8
Effective Communication	8
Performance Monitoring	8
Long-term Relationship Practices	7
Procurement Effectiveness	8
Vendor Challenges	8
Conflict Resolution	8
Compliance Handling	8
Policy & Framework Suggestions	8

Diagram 3: Thematic Analysis by Frequency

Effective communication emerged as a recurring theme across responses. All participants agreed that **open, two-way communication strengthens trust**, reduces the likelihood of disputes, and improves problem resolution. Poor communication, conversely, was cited as a major challenge leading to misunderstandings and delivery delays. The NPRA engineering team particularly noted that frequent communication not only resolves issues swiftly but also fosters a collaborative working environment.

When evaluating performance monitoring mechanisms, various methods were cited, including **monthly performance reviews, user feedback, vendor scorecards, and compliance audits**. These tools help identify gaps early and ensure that vendors adhere to contractual obligations.

Participants found that such evaluations allow for quick intervention when issues arise, reducing the risk of costly disruptions.
In terms of sustaining long-term relationships, organizations have implemented practices like **joint planning meetings, vendor recognition programs**, and involvement in strategic objectives. These measures were credited with maintaining vendor motivation and fostering loyalty. The NPRA and Radicare teams also pointed out that involving vendors in long-term strategies helps build mutual commitment and innovation opportunities.

On procurement effectiveness, the data clearly show that **strong vendor relationships improve procurement outcomes**. These include enhanced service quality, reduced procurement cycle time, fewer errors, and overall cost savings. Several participants provided real-life examples where collaborative vendor efforts led to innovations that streamlined operations or solved supply issues during emergencies.

Nonetheless, several challenges were reported. These include **vendor unresponsiveness, scope misalignment, compliance failures, and pricing disputes**. Such issues, if unmanaged, can hinder project progress and increase risk. To address these problems, organizations reported adopting a range of solutions such as SLA revisions, structured retraining, joint root cause analysis, and escalation frameworks.

Conflict resolution practices also received considerable attention. Most participants preferred **negotiation, documentation of scope, and regular review meetings** as effective methods to prevent or resolve disputes. The use of centralized portals and escalation policies also proved effective in enforcing accountability and compliance.

Finally, participants recommended the adoption of structured frameworks and standards such as **ISO 20400 for sustainable procurement, centralized vendor engagement platforms, onboarding programs**, and integrated performance audits. These frameworks were seen as essential to ensure consistency, improve supplier performance, and mitigate risks.
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5.0 CONCLUSION

The study's findings underscore the critical role that structured vendor relationship management plays in enhancing procurement effectiveness within facilities management. Across all participating organizations UDA HQ, NPRA, and Radicare there is a consistent emphasis on the use of **clear KPIs, SLAs, and regular performance monitoring** as foundational tools for managing vendor relationships effectively. Furthermore, **open communication** emerged as a pivotal factor that not only fosters trust but also enables early issue resolution and better alignment of project goals. The conceptual framework established for this study identifies three core constructs influencing the success of Vendor Relationship Management (VRM): Service Quality, Procurement Efficiency, and Vendor Relationship Effectiveness. These constructs were examined through qualitative interview responses from participants representing UDA HQ, NPRA Engineering Department, and Radicare Facilities Management. The findings from the field strongly support and validate the relevance of this conceptual framework.

The first construct, **Service Quality**, was highlighted in all interviews as a fundamental outcome of effective vendor relationships. Respondents described how reliable vendors, driven by

consistent communication and performance evaluations, improved the timeliness and quality of deliverables. This finding confirms the assertion in the framework that service quality contributes significantly to the strength of VRM. The correlation between open dialogue, mutual understanding, and superior service delivery illustrates the practical manifestation of this relationship.

The second element, **Procurement Efficiency**, was repeatedly mentioned by participants who emphasized the role of clear Key Performance Indicators (KPIs), Service Level Agreements (SLAs), and regular performance monitoring. These mechanisms were reported to streamline procurement workflows, reduce misunderstandings, and improve decision-making. As a result, procurement processes became more efficient, aligning with the framework's position that operational efficiency is a critical enabler of effective vendor relationship management.

Thirdly, **Vendor Relationship Effectiveness** was confirmed through various strategic practices shared by participants, including joint planning, vendor recognition programs, and collaborative problem-solving. These initiatives promote long-term engagement, trust, and innovation all of which are essential for maintaining robust vendor partnerships. The consistent mention of these practices across different organizations highlights their universal importance and reinforces their inclusion in the framework.

In conclusion, the alignment between the conceptual framework and the qualitative findings demonstrates the framework's validity and practical application. The three constructs Service Quality, Procurement Efficiency, and Vendor Relationship Effectiveness are not only theoretically significant but also reflected in real-world procurement practices. This alignment underscores the importance of adopting structured and strategic approaches to vendor relationship management in the facilities sector, and validates the framework as a comprehensive model for assessing and enhancing VRM performance.

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5 PENGURUSAN PELANCONGAN & HOSPITALITI

Exploring Consumer Satisfaction of Malaysian Street Food at Taman Scientex, Pasir Gudang

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ABSTRACT
This research explores the primary elements affecting customer satisfaction regarding street food at Taman Scientex, Pasir Gudang. It emphasizes recognizing the key factors that influence customer satisfaction and how these relate to repeat business and views on food quality. The study holds significant value for local street food vendors, providing actionable insights that can assist them in aligning their services more closely with customer expectations and enhancing their operations. A quantitative research approach was employed, with structured questionnaires given to 203 regular street food customers in the region. The obtained data were examined through descriptive statistics and correlation analysis. The findings show that elements like food quality, sanitation, pricing, vendor conduct, and accessibility significantly influence customer satisfaction. Of these factors, cleanliness and food quality stood out as the most impactful. According to these results, the research proposes implementing hygiene training for vendors and standardizing service protocols to improve customer satisfaction. Future studies might investigate comparable trends in different regions of Malaysia for a more extensive comparison

Keywords: consumer satisfaction, street food, hygiene, food quality, pricing

1.0 INTRODUCTION

1.1 Background of Study
Malaysian street food plays an essential role in the nation's culinary identity, offering affordable and diverse meal choices that reflect the country's multicultural society. In Pasir Gudang, particularly at Taman Scientex, street food is not only popular due to its variety and affordability but also contributes significantly to the local economy.

Customer satisfaction in this context is influenced by several key factors, including vendor attitude, food quality and variety, halal compliance, hygiene standards, pricing, and speed of service. Vendors who excel in these areas are more likely to develop customer loyalty and attract repeat business. Additionally, the convenience of accessing street food especially for busy, time-constrained customers along with the cultural openness of the environment, enhances its overall appeal.

However, while there is substantial research on general factors influencing customer satisfaction with street food such as price, cleanliness, and vendor behavior very few studies have been specifically conducted in Taman Scientex. This creates a knowledge gap in understanding what truly drives satisfaction in this unique local setting.

Understanding customer satisfaction in this specific area is critical because it directly impacts customer return intentions and word-of-mouth promotion both essential for the sustainability of street food vendors. Therefore, this study focuses on identifying the most significant factors influencing consumer satisfaction at Taman Scientex, including elements such as trader friendliness, food quality and variety, halal assurance, and service efficiency. The results aim to

provide valuable insights for vendors and local authorities to improve street food service quality and reputation.

The main goals of this study are to identify the elements influencing customer satisfaction with regard to Malaysian street cuisine. First, the study seeks to assess how polite and charming service affects general consumer satisfaction. Second, it aims to find out how customer contentment is affected by aspects such flavor, personal consumption habits, and the availability of many food variants including halal options. Finally, the study aims to investigate the link among food stall availability, speed of service, and customer degree of happiness.

This study intends to answer several important issues concerning consumer satisfaction with street food from Malaysia. It looks at how polite and appealing service affects customer satisfaction and investigates the degree to which food taste, personal consumption patterns, and the availability of many food options including halal choices affect consumer happiness. The study also looks at the effect on general customer satisfaction of food stall availability and quickness of service.

With an emphasis on four main elements respectful and charming vendor behavior, food taste and consumption experience, the availability of food varieties including halal options, and the accessibility and speed of food stall services this paper investigates the key factors influencing customer satisfaction towards Malaysian street food in Taman Scientex, Pasir Gudang. Although Malaysian street cuisine is much praised for its cost and ethnic diversity, little study has been done particularly in this field. The study intends to close a local knowledge gap and offer significant insights that can help vendors and authorities improve service quality, promote customer loyalty, and strengthen the reputation of the street food sector in Taman Scientex by looking at how these variables affect consumer satisfaction.

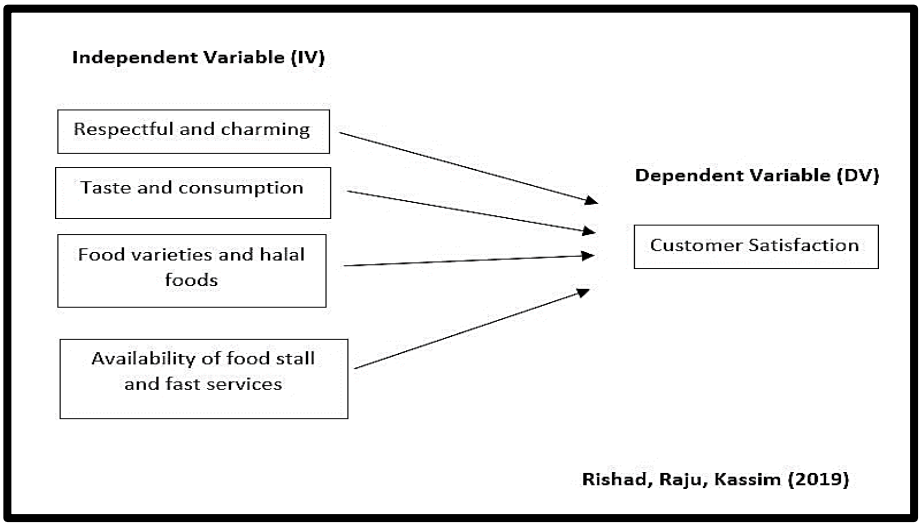

Figure 1: Conceptual Framework

1.2 Literature Review

The street food sector's customer satisfaction is strongly influenced by several important elements. Reasonable pricing, food quality, and hygiene have a high positive correlation, according to Mohamad Zefry Suhaimi Ahmad Suraini et al. (2023). General consumer satisfaction is respectful and courteous contacts with vendors also play a vital role since they improve consumer satisfaction and loyalty by establishing a welcome environment and

therefore generating emotional ties, which in turn drive repeat visits (Lee et al., 2020). Taste is another important consideration, for both local and foreign customers, distinctive, real, and consistent flavours are absolutely vital (Lim & Yap, 2022). Halal-certified food is essential in the Malaysian setting, where most of the population is Muslim, in building confidence and guaranteeing consumer happiness (Ismail & Hashim, 2023). Furthermore, greatly enhancing a good street food experience is the convenience provided by quickly available food vendors and speedy service (Wong & Lim, 2021).

2.0 METHODOLOGY

2.1 Research Methodology Overview

This study adopts a quantitative research approach using a structured questionnaire to investigate the factors influencing customer satisfaction with Malaysian street food in Taman Scientex, Pasir Gudang. The research design is both descriptive and correlational, aiming to examine the relationships between independent variables respectful and charming service, taste and consumption, food variety and halal assurance, and the availability of food stalls with fast service and the dependent variable, customer satisfaction. A cross-sectional survey was conducted among local tourists, defined as Malaysian residents visiting the area. The use of self-administered questionnaires allows for efficient data collection, while a Likert scale format ensures ease of response and statistical analysis.

2.2 Data Collection and Instruments

Based on past research on consumer behavior and food service quality, the questionnaire was developed addressing elements such vendor friendliness, meal flavor, variety, halal compliance, and service speed. Questions concerning the general level of satisfaction, intention to review, and referral likely helped one determine the dependent variable. A pilot study was done to guarantee the validity and dependability of the instrument, Cronbach's alpha was then used to evaluate internal consistency. Using descriptive statistics, reliability testing, and multiple regression analysis, data were examined to ascertain how each independent variable affected customer satisfaction.

2.3 Sampling Method

Targeting a sample size of 384 from an expected population of 30,000, Krejcie and Morgan's (1970) formula allowed one to Practical data collecting among customers of street food was done using convenience sampling. Responses from a varied spectrum of people were gathered using both in-person approaches and internet tools including Google Forms. The results of this study should give insightful analysis of the elements influencing street food satisfaction among local visitors, thereby guiding vendors and local authorities to enhance the whole customer experience in Taman Scientex, Pasir Gudang.

3.0 RESULTS AND DISCUSSION

3.1 Result of Demographic

The demographic profile of the respondents reveals that the majority fall within the age group of 21 to 25 years old (77.3%), followed by 26 to 30 years old (14.3%). Smaller percentages represent the age groups of 16 to 20 (3.9%), 31 to 35 (3%), 41 and above (1%), and 36 to 40 (0.5%). Gender distribution is nearly equal, with 50.2% male and 49.8% female respondents. In terms of profession, most respondents are students (70.4%), while others work in the private sector (17.7%), are unemployed (4.9%), or are either self-employed or work in the government sector (3.4% each). Regarding personal income, a significant majority (76.8%) earn less than

RM 1000 per month, followed by 14.3% earning between RM 1000 and RM 2000, 8.4% earning between RM 2000 and RM 3000, and only 0.5% earning above RM 4000.This demographic profile indicates that the respondents are predominantly young, student-based individuals with relatively low income.

Table 1: Result of Demographic 1

Demographic Variable	Category	Frequency	Percentage (%)
Age	16 - 20 years old. / 16 - 20tahun	8	3.9
	21 - 25 years old. / 21 - 25tahun	157	77.3
	26 - 30 years old. / 26 - 30tahun	29	14.3
	31 - 35 years old. / 31 - 35tahun	6	3
	36 - 40 years old. / 36 - 40tahun	1	0.5
	41 and above. / 41 tahun dan ke atas	2	1
	Total	**203**	**100.0**
Gender	Female / Perempuan	101	49.8
	Male / Lelaki	102	50.2
	Total	**100**	**100.0**
Profession	Government sector / Sektor Kerajaan	7	3.4
	Private sector / Sektor Swasta	36	17.7
	Self-employed / Bekerja Sendiri	7	3.4
	Unemployed / Tidak Bekerja	10	4.9
	Student / Pelajar	143	70.4
	Total	**203**	**100.0**
Personal income per month	Less than RM 1000 / Kurang daripada RM 1000	156	76.8
	RM 1000 - RM 2000	29	14.3
	RM 2000 - RM 3000	17	8.4
	Above RM 4000 / RM 4000dan keatas	1	0.5
	Total	**203**	**100.0**

3.2 Reliability Test

The Respectful and Charming variable consists of 5 items and has a Cronbach's Alpha value of 0.826, indicating a high level of internal consistency. This suggests that the items under this variable reliably measure respondents' perceptions of how courteous, friendly, and pleasant the service providers or staff members are during their interactions.

The Taste and Consumption variable also includes 5 items and records a Cronbach's Alpha of 0.848, showing excellent reliability. This implies that the respondents provided consistent feedback regarding the quality, flavor, and satisfaction of the food they consumed, reflecting their overall dining experience.

The Food Varieties and Halal Foods variable is made up of 5 items and has a Cronbach's Alpha of 0.723, which still indicates acceptable reliability. This means that the items are fairly consistent in capturing respondents' views on the availability of diverse food options, particularly those that are halal and meet dietary requirements.

Lastly, the Availability of Food Stalls and Fast Service variable, with 5 items and a Cronbach's Alpha of 0.777, shows a good level of internal consistency. It reflects respondents' satisfaction with the number of food stalls available and the speed at which service was delivered, which are key aspects of convenience and efficiency in food services.

The overall Cronbach's Alpha value of 0.847 demonstrates that the entire survey instrument used is reliable and the items across all variables are consistently measuring what they are intended to Respectful and Charming

3.3 Descriptive Analysis

Table 2: Ddescriptive Analysis

Variable	Items	Cronbach's Alpha Per Variable	Cronbach's Alpha
Respectful and Charming	5	0.826	0.847
Taste and consumption	5	0.848	
Food varieties and halal foods	5	0.723	
Availability of food stall and fast service	5	0.777	

Descriptive statistics of the study show the general reactions of 198 participants to four key ideas connected to street food in Taman Scientex, Pasir Gudang, and consumer happiness. With a mean score of 4.6788 and a standard deviation of 0.37949, the construct "Respectful and Charming" showed high degree of agreement among respondents with quite low variation. With a standard deviation of 0.45468, the average score for "Taste and Consumption" was 4.5687, therefore implying a typically good impression with somewhat more variance in responses. Reflecting great agreement and consistent answers, the construct "Food Varieties and Halal Foods" had a mean of 4.7091 and a standard deviation of 0.33572. With the lowest standard deviation of 0.32783, "Availability of Food Stalls and Fast Services" got the highest mean score of 4.7354, showing that it was the aspect most consistently rated. Given that every construct had a minimum score of over 3.00 and a maximum of 5.00, it follows that, mostly speaking, respondents had favourable attitudes across all of the domains evaluated

3.4 The result of Descriptive Statistic

Table 3: Result of Descriptive Analysis

Descriptive Statistics					
ITEM	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Respectful and Charming	198	3.80	5.00	4.6788	.37949
Taste and Consumption	198	3.20	5.00	4.5687	.45468
Food Varieties and Halal Foods	198	3.80	5.00	4.7091	.33572
Availability of Food Stalls and Fast Services	198	3.80	5.00	4.7354	.32783
Valid N (listwise)	198				

4.0 CONCLUSION

This study aimed to explore the key factors influencing consumer satisfaction with Malaysian street food in Taman Scientex, Pasir Gudang. The findings reveal that customer satisfaction is significantly shaped by four major elements: respectful and charming vendor service, taste and consumption experience, food variety and halal assurance, and the availability and speed of food services.

Among these, taste and consumption emerged as the most impactful factor, with customer satisfaction explaining 80.1% of the variance ($R^2 = 0.801$), followed closely by food variety and halal foods ($R^2 = 0.691$), and respectful and charming service ($R^2 = 0.662$). ANOVA results confirmed that these relationships are statistically significant ($p < 0.001$), while regression coefficients further reinforced the strong positive influence of customer satisfaction on these dimensions, particularly for taste ($\beta = 0.895$).

The descriptive analysis supports these statistical results, showing high mean scores and strong agreement among respondents, especially regarding the hygiene of food preparation, the friendliness of vendors, and the availability of halal options. Most respondents were young, student-based, and income-constrained, which also emphasizes the importance of affordable, accessible, and culturally appropriate food options.

In conclusion, the study highlights that improving the taste quality, ensuring halal compliance, maintaining clean and friendly vendor behavior, and offering fast and convenient service are essential to enhancing consumer satisfaction. These insights are particularly valuable for local hawkers and authorities aiming to improve service quality and attract repeat customers. Future research could broaden this analysis to include comparisons across different regions or demographic segments to develop a more generalizable model of street food satisfaction in Malaysia.

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Gen Z and Urban Mobility in Johor: Insights into Public Transport Development

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ABSTRACT

This study explores the perceptions of Generation Z (aged 13-28) toward the development of public transportation in Johor, Malaysia, with a focus on accessibility, affordability, safety, digital integration, and sustainability. The aim is to identify the challenges and opportunities for improving public transportation services to meet the needs of this demographic. The research employs a mixed- methods approach, utilizing both quantitative surveys and qualitative interviews with Gen Z residents of Johor. Findings indicate that while this group values digital tools such as real-time tracking and e- ticketing, they also emphasize the importance of affordability and sustainability in public transport. Environmental concerns and safety features were found to be significant drivers for higher adoption rates. The study concludes with recommendations for public transportation providers and policymakers, suggesting the incorporation of more sustainable practices, enhanced digital integration, and improved safety measures to attract Gen Z users.

Keywords: gen z, public transportation, sustainability, digital integration, Johor.

1.0 INTRODUCTION

Public transportation plays a vital role in urban development, contributing to reduced traffic congestion, improved air quality, and enhanced mobility. In Johor, Malaysia, which is experiencing rapid urban growth, public transportation development is crucial to ensure sustainability. The state has introduced infrastructure projects such as the Bus Rapid Transit (BRT) and the Johor Bahru- Singapore Rapid Transit System (RTS), but limited research exists on how Generation Z (Gen Z), the emerging user group, perceives and uses these services.

Generation Z, born between 1997 and 2012, is known for their high digital literacy and environmental consciousness. The Theory of Planned Behavior (TPB) (Ajzen, 1991) is a useful framework for understanding Gen Z's transportation choices, suggesting that attitudes toward sustainability, perceived control, and social norms significantly influence their behavior. Furthermore, the Technology Acceptance Model (TAM) (Davis, 1989) posits that individuals are more likely to adopt new technologies if they find them useful and easy to use. Given their tech-savviness and eco- consciousness, these theories help to explain why Gen Z would favor public transport systems with efficient digital integration and sustainability features. The key research objective are:

i. To assess how Generation Z views the current state of public transportation, focusing on accessibility & convenience, affordability, safety, sustainability, and technological integration.

ii. To investigate how features such as mobile apps, real-time tracking, e-ticketing, and cashless payments influence Gen Z's satisfaction and usage of public transportation.

iii. To identify ways to promote environmentally sustainable practices in public transportation, leveraging Gen Z's environmental awareness and preference for green commuting options.

The study's findings will offer insights for policymakers and transportation service providers to create user-centric and sustainable public transportation solutions tailored to the needs of Gen Z.

1.1 Conceptual Framework

The conceptual framework for this study is built upon the identification of the key factors that influence Generation Z's perceptions of public transportation in Johor. These factors include accessibility, cost, safety, digital integration, and sustainability. Each of these elements plays a crucial role in shaping the overall satisfaction and adoption rates of public transport services. The framework also incorporates relevant theoretical models, such as the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB), to better understand how these variables interact and influence Gen Z's transportation choices.

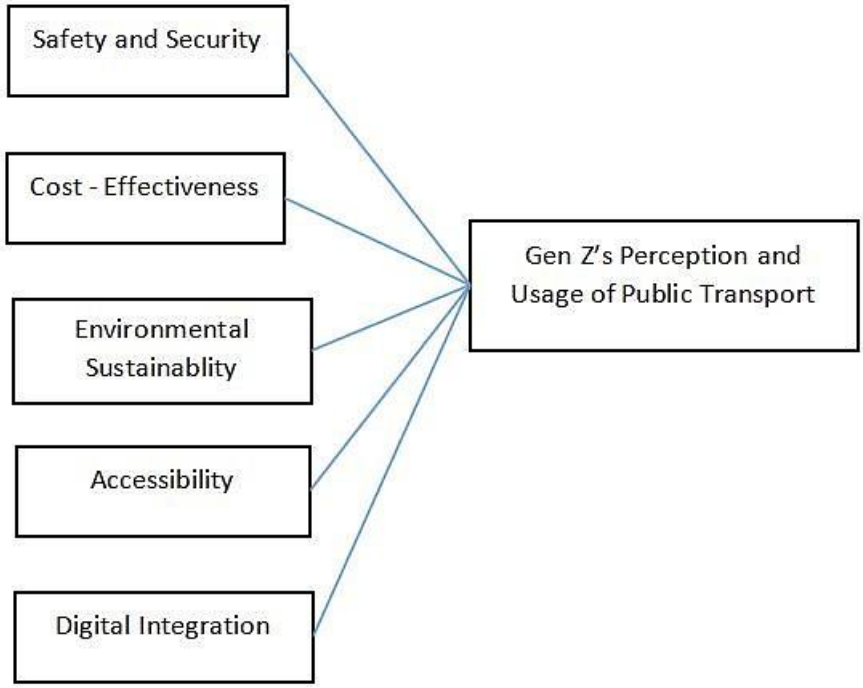

Figure 1: Conceptual Framework

2.0 METHODOLOGY

A quantitative research design was adopted to examine the perceptions of Generation Z toward public transportation in Johor. The study involved 188 respondents aged 13 to 28, selected through convenience sampling. The research instrument was a structured questionnaire based on five-point Likert scales, covering constructs such as Accessibility, Cost, Safety, Digital Integration, Sustainability, and Satisfaction. These constructs were grounded in the Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), and Diffusion of Innovations Theory, offering a comprehensive framework for analysis. The instrument's internal consistency was confirmed through Cronbach's Alpha values, all exceeding 0.88, indicating high reliability. Data were analyzed using SPSS, employing descriptive statistics, correlation

analysis, and multiple regression analysis to explore the relationships between the variables and assess their influence on Gen Z's perception and behavioral intention to use public transportation.

3.0 RESULTS AND DISCUSSION

Results from the study reveal that key factors influencing Gen Z's satisfaction with public transportation include accessibility, affordability, safety, digital integration, and sustainability. These findings support the observations made by Park and Zhang (2021), who found that younger generations, particularly millennials and Gen Z, are highly responsive to the availability of sustainable transport options. Additionally, Shafiqah et al. (2021) found that digital integration, such as the use of real-time tracking and mobile apps, is essential for increasing user satisfaction, which aligns with our findings that Gen Z places a high value on technological convenience

3.1 Tables and Figures

Table 1: Descriptive Statistics for Demographic Profile

Items	Categories	Frequency	Percentage (%)
Age	13 - 16	10	5.3
	16 - 19	34	18.1
	19 - 22	56	29.8
	22 - 25	66	35.1
	25 - 28	22	11.7
	Total	**188**	**100.0**
Gender	Male	95	50.5
	Female	93	49.5
	Total	**188**	**100.0**
Level of Education	Secondary School	41	21.8
	Diploma	47	25.0
	Bachelor's Degree	56	29.8
	Master's Degree or Higher	33	17.6
	Doctor of Philosophy (PhD)	11	5.9
	Total	**188**	**100.0**
Occupation	Student	65	34.6
	Employee	57	30.3
	Self-employed	37	19.7
	Unemployed	29	15.4
	Total	**188**	**100.0**

Table 1 presents the demographic characteristics of the 188 respondents, highlighting key factors such as age, gender, education, and occupation, which offer important context for understanding the study's findings. Most respondents (35.1%) were in the 22-25 age group, followed by 29.8% in the 19-22 range. A smaller percentage (18.1%) were between 16-19 years, and 11.7% were in the 25-28 age group. Only 5.3% were between 13-16 years, indicating that

the majority of respondents were young adults, fitting the Gen Z profile. In terms of gender, the distribution was nearly equal, with 50.5% male and 49.5% female, ensuring a balanced perspective in the study. Regarding education, most respondents had a Bachelor's degree (29.8%), followed by those with a Diploma (25.0%) and Secondary School qualification (21.8%). Those with higher education (Master's or PhD) made up 23.5% of the sample, showing a relatively well-educated group. As for occupation, the largest proportion were students (34.6%), followed by employees (30.3%), self-employed individuals (19.7%), and unemployed respondents (15.4%). This diversity in occupation adds to the variety of insights into public transportation experiences across different demographic groups.

Table 2: Reliability Analysis of Data Set

Construct	Items	Number of Items	Cronbach's Alpha Per Variable
Accessibility	B1-B5	5	0.890
Cost	C1-C5	5	0.888
Safety	D1-D5	5	0.884
Digital Integration	E1-E5	5	0.897
Sustainability	F1-F5	5	0.909
Satisfaction	G1-G5	5	0.887

Table 2 presents the reliability test results for the constructs measured in the study. Cronbach's Alpha coefficients were calculated for each of the six constructs, with five items in each section. An Alpha value above 0.70 indicates that the items are consistently measuring the same factor.

For the Accessibility construct (B1–B5), the Cronbach's Alpha was 0.890, indicating very high reliability, meaning that the items accurately reflect respondents' perceptions of how accessible public transport services are. Similarly, the Cost construct (C1–C5) had an Alpha of 0.888, demonstrating high reliability in measuring affordability and pricing satisfaction in public transport services. The Safety construct (D1–D5) produced an Alpha of 0.884, suggesting that the items related to personal security and safety norms were consistent and reliable. The Digital Integration construct (E1–E5) had an Alpha of 0.897, signifying superior consistency, indicating that respondents' attitudes toward digital services such as real-time tracking and e-ticketing were reliably measured. The Sustainability construct (F1–F5) had the highest Alpha of 0.909, confirming that the items effectively gauge respondents' views on green and sustainable practices in public transport. Finally, the Satisfaction construct (G1–G5) showed an Alpha of 0.887, indicating that the items measuring overall satisfaction with public transport services were consistently reliable.

In total, all constructs showed good to high internal consistency, confirming the reliability of the survey instrument and providing confidence that the data collected is reliable for further analysis.

Table 3: Descriptive Statistics for Variable

Variables	Grand Mean	Std. Deviation
Accessibility	3.5670	1.00031
Cost	3.6777	0.98227
Safety	3.5787	0.93396
Digital Integration	3.7128	0.97083
Sustainability	3.7915	1.02354
Satisfaction	3.7213	0.93544

Table 3 presents the descriptive statistics for six key factors influencing public transport in Johor: Accessibility, Cost, Safety, Digital Integration, Sustainability, and Satisfaction. Sustainability received the highest average rating (3.7915), indicating strong support for green initiatives, though it also had the highest variability (1.0235), reflecting differing levels of awareness. Satisfaction followed closely (3.7213), with moderate consistency (0.9354), suggesting general contentment. Cost (3.6777) and Safety (3.5787) were rated moderately, with relatively stable opinions. Accessibility (3.5670) had the lowest rating and highest variation (1.0003), highlighting ongoing concerns, likely due to infrastructure disparities. Digital Integration (3.7128) showed positive feedback but with moderate variation (0.9708), pointing to differences in technology use and availability. Overall, while respondents were positive about sustainability, satisfaction, and digital features, there remain challenges in accessibility that need addressing for more consistent and user-friendly services.

Table 4: Pearson Correlation Coefficient Matrix

	Accessibility	Cost	Safety	Digital_Integration	Sustainability	Satisfaction
Accessibility	1	.862**	.898**	.834**	.781**	.855**
Sig. (2-tailed)		<.001	<.001	<.001	<.001	<.001
N	188	188	188	188	188	188
Cost	.862**	1	.893**	.914**	.906**	.926**
Sig. (2-tailed)	<.001		<.001	<.001	<.001	<.001
N	188	188	188	188	188	188
Safety	.898**	.893**	1	.880**	.819**	.896**
Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001
N	188	188	188	188	188	188
Digital_Integration	.834**	.914**	.880**	1	.879**	.904**
Sig. (2-tailed)	<.001	<.001	<.001		<.001	<.001
N	188	188	188	188	188	188
Sustainability	.781**	.906**	.819**	.879**	1	.926**
Sig. (2-tailed)	<.001	<.001	<.001	<.001		<.001
N	188	188	188	188	188	188
Satisfaction	.855**	.926**	.896**	.904**	.926**	1
Sig. (2-tailed)	<.001	<.001	<.001	<.001	<.001	
N	188	188	188	188	188	188

Note: ** Correlation is significant at the 0.01 level (2-tailed).

In table 4, A pearson correlation analysis was conducted to examine the relationships between the main variables of Accessibility, Cost, Safety, Digital Integration, Sustainability, and Satisfaction. The results revealed that all independent variables have strong positive correlations with Satisfaction (all at the 0.01 level), indicating that improvements in these areas are linked to higher user satisfaction.

The strongest correlations were found between Satisfaction and Cost, Sustainability, and Digital Integration (r = .926), followed closely by Safety (r = .896) and Accessibility (r = .855). Additionally, the independent variables themselves showed high intercorrelations, such as Cost with Digital Integration and Sustainability, and Safety with Accessibility and Cost, suggesting that improvements in one area often enhance others. These findings support the hypothesis that

better performance in Accessibility, Cost, Safety, Digital Integration, and Sustainability leads to higher satisfaction, with subsequent analyses like multiple regression recommended to further explore the unique contributions of each variable.

Table 5: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.960[a]	.922	.920	.26407

Table 6: ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	150.944	5	30.189	432.929	<.001[b]
	Residual	12.691	182	.070		
	Total	163.635	187			

a. Dependent Variable: Satisfaction

b. Predictors: (Constant), Sustainability, Accessiblility, Digital Integration, Safety, Cost

Table 7: Coefficients

Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		
	Sustainability	Std. Error	Beta	t	Sig.
(Constant)	.178	.079		2.240	.026
Accessiblility	.080	.046	.086	1.737	.084
Cost	.145	.065	.152	2.247	.026
Safety	.233	.058	.232	4.013	<.001
Digital_Integration	.097	.055	.100	1.760	.080
Sustainability	.404	.047	.442	8.655	<.001

A multiple linear regression analysis was conducted to examine how the independent variables Accessibility, Cost, Safety, Digital Integration, and Sustainability—affect Satisfaction in public transportation in Johor. The model showed a strong positive correlation ($R = 0.960$) and explained 92.2% of the variation in Satisfaction (R Square = 0.922), with a low standard error of 0.26407, indicating accurate predictions. ANOVA results confirmed the model's significance (F-statistic = 432.929, $p < 0.001$), showing that the independent variables collectively predict Satisfaction effectively. Regression coefficients revealed that Sustainability (Beta = 0.442, $p < 0.001$) had the most significant impact on Satisfaction, followed by Safety (Beta = 0.232, $p < 0.001$) and Cost (Beta = 0.152, $p = 0.026$). Digital Integration (Beta = 0.100, $p = 0.080$) and Accessibility (Beta = 0.086, $p = 0.084$) showed weaker or marginal effects. The results suggest that Sustainability, Safety, and Cost are strong predictors, while Digital Integration and Accessibility may require further exploration for their impact on user satisfaction.

4.0 CONCLUSION

In the context of Johor's public transportation system, this study's empirical findings highlight that accessibility, affordability, safety, sustainability, and digital integration are key dimensions that shape Gen Z's satisfaction and willingness to adopt public transport. The results offer valuable insights specific to the Gen Z demographic, while reinforcing established theoretical models such as the Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), and Diffusion of Innovations Theory. While infrastructure and affordability remain important, digital integration and environmental consciousness significantly influence behavioral intention among younger users. By bridging a critical knowledge gap, this study provides actionable strategies for transportation planners and policymakers to design more user-centric, tech-driven, and sustainable urban mobility solutions that align with Gen Z's values and expectations.

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Heritage Preservation in the Modern Era: The Role of the *Kereta Api Sarong* Event in Sustaining Malaysian Cultural Traditions

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ABSTRACT

Tourism plays a vital role in the development of identity and the expression of culture, especially in the context of increasing urbanization and globalization, which threaten the preservation of traditional practices. The *Kereta Api Sarong* event in Malaysia represents a public cultural initiative designed to promote national heritage through interactive and participatory experiences. By encouraging participants to wear traditional sarongs while utilizing public transportation, the event symbolically bridges the gap between cultural traditions and contemporary urban life. This study aims to examine the cultural impact of the *Kereta Api Sarong* event, focusing on its contributions to cultural identity formation, the enhancement of historical awareness, the strengthening of intergenerational relationships, and the promotion of intercultural interaction among Malaysia's diverse ethnic communities. A quantitative research design was employed, involving 534 valid responses collected through an online survey. The data were analyzed using SPSS, revealing statistically significant effects across all four dimensions examined.The findings underscore the importance of cultural events in fostering national identity and social inclusivity. This research contributes valuable insights for cultural policymakers, governmental bodies, and tourism stakeholders, highlighting the potential of heritage- based tourism initiatives to support sustainable cultural preservation through active public engagement and perceived cultural value.

Keywords: preserving heritage; cultural identity; historical narrative; intergenerational bond; cross-cultural interaction

1.0 INTRODUCTION

Cultural heritage reflects a society's identity, values, and traditions passed through generations (Cudny et al., 2021). Yet, globalization, urbanization, and the homogenization of cultural expressions threaten its continuity, particularly among younger generations. This creates an urgent need for innovative strategies to bridge tradition and modernity. Integrating cultural events within tourism frameworks offers one such solution, as seen in reenactments and festivals that raise awareness, generate economic benefits, and strengthen communal identity (Timothy & Boyd, 2003; Cudny et al., 2021). Poland's Dymarki Swietokrzyskie festival exemplifies how historical reenactments can sustain both tangible and intangible heritage.

In Malaysia, the *Kereta Api Sarong* festival presents a unique model by combining traditional attire with modern public transport, reinforcing cultural pride in an urban context. While such events demonstrate potential for enhancing identity and promoting cultural tourism (Poria et al., 2003; Richards, 2001), their impact remains under-researched particularly in non-Western settings. Existing studies often overlook how these practices shape individual identity and participation in heritage preservation. This study seeks to fill that gap by examining the role of the *Kereta Api Sarong* in sustaining Malaysian cultural traditions through the lenses of Cultural Heritage and Identity, Modernization and Tradition, and Cultural Tourism.

1.1 Research Objective

This study aims to explore the cultural significance and social impact of the *Kereta Api Sarong* event within the context of Malaysian heritage preservation. The specific objectives are:

- To determine the role of *Kereta Api Sarong* in shaping cultural identity among participants and the community
- To examine the influence of *Kereta Api Sarong* in improving understanding and appreciation of Malaysia's cultural history.
- To examine the effectiveness of the event in creating shared experiences between older and younger participants.
- To examine *Kereta Api Sarong* promotes social connection among people of various ethnic and cultural backgrounds.

These objectives align with the broader goal of understanding how cultural events contribute to heritage preservation in contemporary society.

1.2 Research Question

Based on the objectives outlined above, this study is guided by the following research questions:

- How does *Kereta Api Sarong* influence the cultural identity of its participants and the wider community?
- How does *Kereta Api Sarong* enhance public appreciation of Malaysia's historical narratives?
- How does the event create shared cultural experiences for older and younger participants?
- How does *Kereta Api Sarong* facilitate interactions between individuals of different ethnic and cultural backgrounds?

1.3 Conceptual Framework

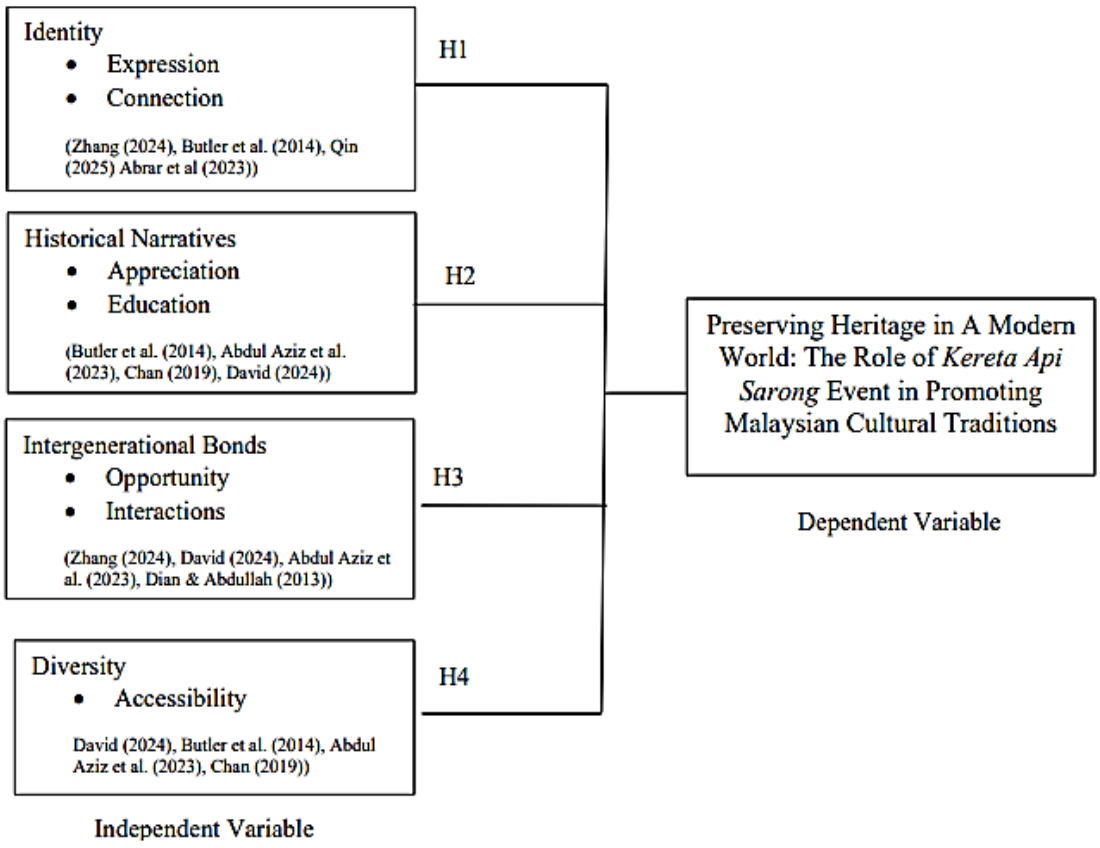

Figure 1: Conceptual Framework

2.0 METHODOLOGY

This chapter outlines the research methodology used to investigate the role of the Kereta Api Sarong event in promoting Malaysian cultural traditions. It details the research design, data collection methods, instruments, sampling techniques, and data analysis strategies. A quantitative approach was adopted to obtain statistically valid insights into public perception and engagement with the event.

2.2 Research Design

This study employs a quantitative research design to examine the impact of the Kereta Api Sarong event on cultural heritage preservation in contemporary Malaysia. Rooted in a positivist paradigm, the research uses a deductive approach to test theory through measurable data. Four independent variables cultural identity, historical narratives, intergenerational relations, and diversity were assessed for their influence on the dependent variable: heritage preservation.

2.3 Data Collection Method

Data were collected using a structured questionnaire designed to measure respondents' attitudes and perceptions of the event. This method facilitated the collection of standardized, quantifiable data, enabling the identification of trends and patterns related to cultural preservation.

2.3.2 Quantitative Research

Quantitative research was used to analyze numerical data and test hypotheses derived from the

conceptual framework. A survey was administered to participants of the *Kereta Api Sarong* event to assess their experiences and perceptions.

2.4 Research Instrument

The primary research instrument was a standardized questionnaire structured around the study's conceptual framework. It used a five-point Likert scale and was divided into six sections:

- Section A: Demographics (age, gender, ethnicity, nationality, occupation)
- Section B: Cultural identity
- Section C: Historical narratives
- Section D: Intergenerational relations
- Section E: Diversity
- Section F: Heritage preservation

The questionnaire was distributed online via Google Forms to ensure accessibility and reach among event participants.

2.5 Data Analysis Method

Data were processed using SPSS. Initial steps included data cleaning and screening for accuracy. Descriptive statistics (frequencies, percentages, means, and standard deviations) summarized demographic profiles and response trends. Inferential statistics, including correlation and regression analyses, were applied to test relationships among variables and to evaluate the impact of independent variables on heritage preservation.

2.6 Sampling

The study utilized proximity sampling with simple random allocation. Respondents included active participants of the *Kereta Api Sarong* event, particularly those who shared their experiences on social media. Based on the Krejcie and Morgan (1970) sample size table, a minimum of 377 respondents was deemed sufficient for the target population of 20,000 participants recorded in 2024. This ensures the reliability and validity of the study's findings.

3.0 RESULTS AND DISCUSSION

This chapter presents the results of data collected from 534 respondents who participated in the *Kereta Api Sarong* event and shared their experiences through social media. The sample size exceeds the minimum requirement of 384 (Krejcie & Morgan, 1970), ensuring strong data reliability and credibility.

Data were collected using a structured questionnaire designed to assess public perception regarding the event's role in preserving Malaysian cultural heritage. The questionnaire addressed key constructs aligned with the research objectives: cultural identity, historical narratives, intergenerational bonds, diversity, and heritage preservation.

Quantitative data were analysed using SPSS, focusing on descriptive statistics and regression analysis. Each construct was measured through multiple items rated on a five-point Likert scale, and results are presented through the mean scores for each item and variable, the overall mean score, and the standard deviation. This approach allows for a clear interpretation of respondent consensus and variability across constructs.

By analysing the mean scores and standard deviation, this chapter provides insight into how participants perceive the event's effectiveness in fostering cultural identity, enhancing historical understanding, encouraging intergenerational engagement, promoting diversity, and contributing to heritage preservation. Regression analysis was also conducted to examine the relationship between the independent variables and heritage preservation; the results of this analysis are discussed in detail in a subsequent section.

Table 1: Descriptive Analysis

Variables	Mean Per Variable	Mean	Std. Deviation
Identity	4.38		
Historical Narratives	4.29		
Integrational Bonds	4.34	4.34	0.578
Diversity	4.34		
Heritage	4.35		

Table 1 shows the descriptive analysis of the five main variables Identity, Historical Narratives, Intergenerational Bonds, Diversity, and Heritage revealed consistently high mean scores, indicating a strong agreement among participants regarding the cultural impact of the *Kereta Api Sarong* event. The highest mean was recorded under Identity (M = 4.38), suggesting that the event plays a significant role in strengthening participants' sense of cultural identity and pride. Historical Narratives received a slightly lower mean of 4.29, indicating that respondents generally agreed the event improves their understanding and appreciation of Malaysia's cultural history. Intergenerational Bonds and Diversity both shared a mean score of 4.34, reflecting the event's success in fostering shared experiences across age groups and encouraging interaction among individuals from various ethnic and cultural backgrounds. The Heritage variable also scored highly at 4.35, supporting the view that the event contributes positively to the continuity and preservation of cultural traditions in a contemporary setting. The overall mean across all variables was 4.34, with a standard deviation of 0.578, indicating a strong level of consensus and minimal variation in participants' responses. These findings affirm the Kereta Api Sarong event's effectiveness in promoting cultural heritage, enhancing social cohesion, and sustaining traditional values in the context of modern Malaysia.

3.1 Regression Analysis

Simple linear regression was employed to examine the influence of each independent variable Identity, Historical Narratives, Intergenerational Bonds, and Diversity on the dependent variable of heritage preservation. The analysis used standardized beta coefficients to indicate the strength and direction of each relationship, with higher absolute values reflecting stronger effects. Standard errors were used to assess the precision of these estimates, and t- values were evaluated for statistical significance, with values above ±2 considered meaningful. This method enabled the identification of key factors from the *Kereta Api Sarong* event that significantly impact public perception and support for cultural heritage preservation.

Table 2: Regression Analysis

Hypothesis	Std Beta	Std Error	t-Value	Decision
Identity	0.904	0.017	48.837	Supported
Historical Narrative	0.917	0.017	52.860	Supported
Intergenerational Bonds	0.962	0.012	80.814	Supported
Diversity	0.962	0.012	80.814	Supported

Dependent Variable: Preserving Heritage in A Modern World: The Role of Kereta Api Sarong Event in Promoting Malaysian Cultural Traditions

Table 2 shows the regression analysis was conducted to assess the influence of four independent variables Identity, Historical Narrative, Intergenerational Bonds, and Diversity on the dependent variable: Heritage Preservation through the *Kereta Api Sarong* event. All four hypotheses were statistically supported, as indicated by high standardized beta coefficients (β), low standard errors, and significant t-values, all well above the threshold of ±2. Intergenerational Bonds and Diversity showed the strongest influence on heritage preservation, with the highest standardized beta values of 0.962 and corresponding t-values of 80.814, indicating strong positive relationships and high significance. This suggests that the event effectively fosters cross-generational engagement and inclusiveness across cultural backgrounds. Historical Narrative also had a strong effect ($\beta = 0.917$, $t = 52.860$), showing the event's role in enhancing public understanding of Malaysia's cultural past. Identity, though slightly lower ($\beta = 0.904$, $t = 48.837$), remains a significant factor, underscoring how the event contributes to reinforcing a sense of cultural belonging among participants. Overall, the results confirm that each of the four dimensions significantly contributes to the preservation of cultural heritage, validating the event's multidimensional impact on Malaysian society.

4.0 CONCLUSION

This study explored how the *Kereta Api Sarong* event supports Malaysian cultural heritage through identity building, historical awareness, intergenerational bonding, and diversity.Findings from 534 participants showed strong positive impacts in all four areas, confirming that the event effectively promotes cultural pride, unity, and informal learning.

4.1 Discussion

The event enhanced participants' sense of Malaysian identity, raised heritage awareness, fostered meaningful intergenerational interaction, and encouraged cross-cultural unity. These outcomes support all research objectives and demonstrate the event's role as a dynamic platform for heritage preservation in a modern context.

4.2 Recommendations

Academically, this study adds to cultural identity literature and highlights the value of informal heritage programs. Future research should include diverse events and use mixed methods for deeper insights. Practically, *Kereta Api Sarong* should be institutionalized by cultural agencies, partnered with transport providers, promoted through digital platforms, and improved with post-event evaluations to ensure inclusive and impactful cultural engagement.

4.3 Limitations

This study focused on one event, with limited literature access, time constraints, and a quantitative approach. Broader participant groups, more events, and mixed-method studies are recommended for future research to enhance generalizability and depth.

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Investigating Youth Participation in Community-Based Tourism to Drive Innovation Using Technology Acceptance Model

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ABSTRACT

This study investigates the role of youth in driving innovation within Community-Based Tourism (CBT) by exploring their acceptance and use of digital technology, using the Technology Acceptance Model (TAM) as a theoretical framework. The main aim is to examine how perceived usefulness and perceived ease of use influence the behavioral intention of youth to adopt technology in CBT activities, with a focus on Homestay Kampung Lukut, Johor. The significance of this study lies in addressing the gap in rural tourism literature regarding youth engagement and their contribution to digital transformation in local tourism development. A quantitative research method was employed, using a structured questionnaire distributed to 100 youth participants. Descriptive and inferential statistical analyses, including regression, were conducted to analyze the data. The findings revealed that both perceived usefulness and perceived ease of use significantly influence behavioral intention, with perceived usefulness emerging as the stronger predictor. Youth respondents demonstrated strong agreement on the benefits and simplicity of using technology in CBT, alongside a high level of intention to engage in innovative digital practices. However, weak correlations suggest the influence of other contextual factors. The study concludes that youth are motivated to adopt technology in CBT and recommends the integration of youth-led digital strategies, infrastructure support, and targeted training programs to enhance innovation in rural tourism. Future research should expand the model to include additional variables and broader geographic contexts.

Keywords: youth participation, community-based tourism, technology acceptance model, digital innovation, rural tourism

1.0 INTRODUCTION

Tourism plays a vital role in supporting economic growth, preserving culture, and empowering local communities, especially in developing areas (UNWTO, 2022). One effective model is Community-Based Tourism (CBT), where local residents are directly involved in planning and managing tourism to ensure they benefit socially and economically (Giampiccoli & Saayman, 2018). CBT not only brings income but also helps preserve cultural heritage, protect the environment, and strengthen community bonds (Asmelash & Kumar, 2019; Novelli et al., 2022). Among all groups involved, youth are seen as key drivers of innovation due to their creativity, adaptability, and strong digital skills (George et al., 2021; UN, 2023). Despite this, youth participation in CBT is still limited, particularly in rural areas like Kampung Lukut, Johor (Rahim et al., 2022).

To understand what influences youth involvement in CBT, this study uses the Technology Acceptance Model (TAM) developed by Davis (1989). TAM is widely used to study how people accept and use technology, focusing on two main factors: Perceived Usefulness and Perceived Ease of Use (Venkatesh & Davis, 2000; Marangunić & Granić, 2015). These factors help explain whether someone is likely to adopt digital tools and get involved in innovation-based activities. Applying this model in the tourism setting, the study explores how these

perceptions affect youth participation in CBT. Focusing on Kampung Lukut, the research aims to identify what motivates youth to join CBT, how they contribute to innovation, and what strategies can encourage their active role in rural tourism. The findings aim to fill gaps in current research and provide useful guidance for tourism planners, local leaders, and policymakers (Yusof et al., 2023; Bakar et al., 2023).

1.1 Research Objective

i To explore **perceived usefulness of CBT** in increasing youth innovation in Kampung Lukut, Kota Tinggi.

ii To examine **perceived ease to use CBT** in encouraging innovation of youth in Kampung Lukut, Kota Tinggi.

iii To examine the **behavioral intentions** of youth to participate in driving innovation within community-based tourism (CBT) in Kampung Lukut, Kota Tinggi.

1.2 The Research Question

i How do youth perceive the usefulness of CBT in driving innovation within Kampung Lukut?

ii How do youth perceive the ease of participating in CBT to foster innovation in Kampung Lukut?

iii What factors influence the behavioral intentions of youth to actively participate in CBT and contribute to innovation in Kampung Lukut?

1.3 Conceptual Framework

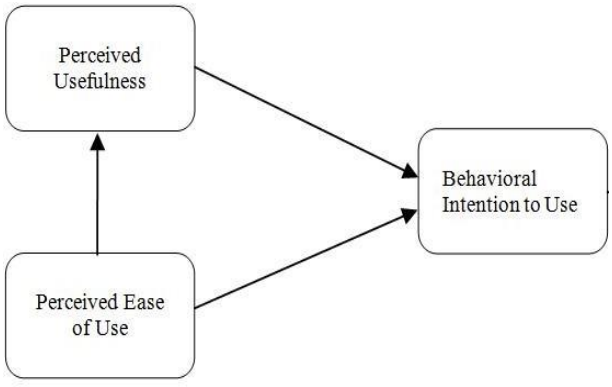

Figure 1: Conceptual Framework

2.0 LITERATURE REVIEW

2.1 Definition of Tourism Industry

Tourism is when people travel to places outside their usual surroundings for fun, business, or

other reasons. According to the World Tourism Organization (2020), tourism includes social, cultural, and economic activities linked to people's travel. It's not just about visiting new places it also affects local cultures, economies, and communities in many ways.

2.2 Definition of Community-Based Tourism (CBT)

Community-Based Tourism (CBT) is tourism that is led and managed by the local community. The goal is to bring benefits directly to the people who live there while protecting their culture and environment. The World Wildlife Fund (2001) says CBT helps visitors learn about local life. It encourages residents to be involved and ensures that profits stay within the community.

2.3 Community-Based Tourism in Malaysia

In Malaysia, CBT is supported by the Ministry of Tourism, Arts, and Culture (MOTAC). It encourages communities to plan and run tourism activities that protect their traditions, culture, and environment. The aim is to give locals more income while offering tourists a real and meaningful experience (TwentyTwo13, 2023).

2.4 Definition of Investigating

Investigating means carefully studying or examining something. In this study, it refers to understanding how communities and youth take part in CBT, what benefits they gain, and what challenges they face. It also involves finding out how their involvement affects tourism development.

2.5 Definition of Youth

Youth refers to young people who are moving from childhood to adulthood. They are usually between the ages of 15 to 30 in Malaysia (Bernama, 2023). Youth are important in tourism because they are creative, good with technology, and open to new ideas. They are seen as the driving force for innovation and change in community development.

2.6 Definition of Innovation

Innovation in tourism means introducing new ideas, services, or ways of doing things that improve tourism experiences. It can involve using technology to make things better. Youth are often the ones who bring innovation, especially with digital tools and creative thinking (Fuchs, 2018; Chen, 2016).

3.0 METHODOLOGY

This chapter explains how the study was carried out to understand how youth participate in Community-Based Tourism (CBT) and how technology helps drive innovation. It includes the research design, methods of data collection, sampling, and how the data were analyzed. The approach was structured to make sure the research results are valid and reliable.

3.1 Research Design

This study used a **quantitative research design** to collect numerical data and examine the relationship between variables. A **cross-sectional** method was used, which means data were collected at one point in time. This method helps in identifying patterns in youth behavior related to technology use in CBT.

The **independent variables** in this study are:
- Perceived Usefulness (PU)
- **Perceived Ease of Use (PEU)**

The **dependent variable** is:
- Behavioral Intention (BI)

These variables were tested using **multiple regression analysis** to see how PU and PEU affect youth intention to use technology in CBT.

3.2 Data Collection Method

A **self-administered questionnaire** was used to collect data from youth in Kampung Lukut, Kota Tinggi, Johor. The questionnaire had two sections:

Section A: Demographic Information (age, gender, education level, employment status, and academic year).
Section B: Measurement of main constructs using **Likert-scale items**.

The survey was distributed both **online (Google Forms)** and **in-person** to reach more participants. Respondents were aged **18 to 35**, which fits the study's focus on youth involvement in technology and tourism.

3.4 Sampling

3.4.1 Target Population

The target respondents were **youth aged 18–35** in **Kampung Lukut, Kota Tinggi, Johor**. This group was selected because they are most likely to influence innovation in CBT using technology.

3.4.2 Sampling Method

The study used **convenience sampling**, meaning respondents were selected based on availability and willingness to participate. This method is useful for small-scale, focused studies like this.

3.4.3 Sample Size

According to **Krejcie and Morgan's (1970)** table, the appropriate sample size for a population of 130 is **97 respondents**. This study collected data from **100 youth**, which is sufficient to provide meaningful and reliable results.

4.0 RESULTS AND DISCUSSION

4.1 Respondent Profile

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	50	50.0
	Female	50	50.0
Age	15–19 years	1	1.0
	20–24 years	49	49.0

	25–30 years	36	36.0
	Above 30 years	14	14.0
Educational Level	SPM	9	9.0
	Diploma	37	37.0
	Bachelor's Degree	53	53.0
	Master's Degree	1	1.0
	PhD	0	0
Employment Status	Employed	38	38.0
	Student	35	35.0
	Self-Employed	20	20.0
	Unemployed	7	7.0

A total of 100 participants were involved in this study. The demographic profile is summarized below:

The **gender distribution** was evenly split, with 50 males and 50 females. This balance ensures that the findings reflect perspectives from both genders equally.

In terms of **age**, most participants were between **20–24 years old** (49%), followed by **25–30 years old** (36%). A smaller number were **above 30** (14%), and only **1%** were in the **15–19 age group**, confirming that the majority were young adults—aligned with the study's focus on youth in community-based tourism.

For **education level**, over half of the respondents held a **Bachelor's degree** (53%), and 37% had a **Diploma**. Only 9% had completed **SPM**, while 1% held a **Master's degree**. This indicates that most participants had higher education backgrounds, potentially influencing their digital skills and openness to technology use.

Regarding **employment status**, 38% were **employed**, 35% were **students**, 20% were **self-employed**, and 7% were **unemployed**. This shows a mix of working individuals, students, and entrepreneurs, reflecting diverse economic backgrounds within the youth population.

4.2 Reliability Test

Table 2: Test of Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SEMUA	.232	100	<.001	.809	100	<.001

a. Lilliefors Significance Correction

According to Pallant (2007), normally distributed data typically form a symmetrical, bell-shaped curve with most values centered around the mean. Testing for normality is important because many statistical tests rely on this assumption. To check for normality, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used. The **Kolmogorov-Smirnov test** produced a statistic of **0.232** with a **significance value below 0.001**, while the **Shapiro-Wilk test** showed

a statistic of **0.809**, also with a **significance value less than 0.001**. Since both p- values are below the standard threshold of 0.05, the results confirm that the data do **not follow a normal distribution**. Therefore, the assumption of normality is violated, and the use of **non-parametric statistical methods** is more suitable for further analysis. These methods are appropriate for data that are skewed or not normally distributed.

4.3 Descriptive Test

Based on the descriptive analysis, the item **PU3** ("Leveraging digital platforms in Homestay Kampung Lukut helps me generate new income opportunities through innovative tourism activities") had the highest mean score of **M = 4.63** and a standard deviation of **SD = 0.58**. This suggests that most youth respondents strongly agree that digital platforms can help them innovate and create income through tourism. The item with the lowest mean score was **BI2** ("I am willing to be actively involved in CBT activities that use technology to promote tourism"), with a mean of **M = 4.37** and **SD = 0.71**. Although the score is still high, it indicates that some respondents were slightly less confident or consistent in their willingness to participate actively. For the **Perceived Usefulness** (PU) construct, all items scored above **M = 4.5**, indicating strong agreement that technology is beneficial for innovation in CBT. In the **Perceived Ease of Use** (PEU) category, the mean scores ranged from **M = 4.40** to **M = 4.50**, showing that respondents generally find the technology easy to use, though with slightly more variation. For **Behavioral Intention** (BI), scores ranged between **M = 4.37** and **M = 4.50**, suggesting that most youth intend to use technology in CBT, though some are less certain about their level of involvement. **Overall**, the results show that youth have a **positive perception** of technology's usefulness and ease of use in community-based tourism and demonstrate a **strong intention** to use it for tourism-related innovation.

Table 3: Descriptive Statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PU1	100	3.00	5.00	4.5968	.55691
PU2	100	3.00	5.00	4.5323	.61983
PU3	100	3.00	5.00	4.6290	.57926
PU4	100	3.00	5.00	4.5968	.61297
PU5	100	3.00	5.00	4.5806	.64142
PEU1	100	3.00	5.00	4.4677	.67064
PEU2	100	3.00	5.00	4.5000	.64655
PEU3	100	3.00	5.00	4.4355	.71566
PEU4	100	3.00	5.00	4.4032	.71195
BI1	100	3.00	5.00	4.4032	.68854
BI2	100	3.00	5.00	4.3710	.70673
BI3	100	3.00	5.00	4.5000	.69542
Valid N (listwise)	100				

4.4 Descriptive Analysis

Table 4: Descriptive Statistics for every section

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PU	100	3.20	5.00	4.5871	.55263
PEU	100	3.00	5.00	4.4516	.63993
BI	100	3.00	5.00	4.4247	.64492
Valid N (listwise)	100				

A total of 100 respondents took part in this study, which looked at three main areas: **Perceived Usefulness (PU)**, **Perceived Ease of Use (PEU)**, and **Behavioral Intention (BI)**. The results show that overall, youth have a positive view of using technology in community- based tourism (CBT). For **Perceived Usefulness**, the average score was **4.59**, meaning most respondents strongly agreed that technology helps them innovate, earn income, and support tourism in their communities. For **Perceived Ease of Use**, the average score was **4.45**, showing that respondents generally find technology easy to learn and use. There was a bit more variation in answers, which means some may have different levels of comfort or experience. For **Behavioral Intention**, the average score was **4.42**, indicating a strong intention to use technology in CBT. However, this score was slightly lower than the other two, suggesting that while most youth want to be involved, a few may still feel unsure or face challenges. In summary, the study shows that youth see technology as useful and easy to use, and most are willing to apply it in CBT. This highlights the potential for technology to support innovation and youth involvement in rural tourism.

4.5 Regression Analysis

4.5.1 Regression Analysis Research for Overall Perceived Usefulness, Perceived Ease to Use and Behavioral Intention

Table 5: Regression Model Summary

Model	R	R^2	Adjusted R^2	Std. Error
1	0.957	0.915	0.930	0.204

Table 6: Anova Result

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	22.862	1	22.862	546.710	<.001
Residual	2.509	100	0.042		
Total	25.371	101			

Table 7: Regression Coefficients

Predictor	Unstandardized B	Std. Error	Standardized Beta	t	Sig.
(Constant)	-0.382	0.207	—	-1.844	0.070
Perceived Usefulness	0.52	0.039	0.705	13.333	<.001
Perceived Ease of Use	0.36	0.046	0.528	9.000	0.001

The regression analysis results indicate that both **Perceived Usefulness (PU)** and **Perceived Ease of Use (PEU)** have **statistically significant and positive effects** on the **Behavioral Intention (BI)** of youth to use technology in Community-Based Tourism (CBT). Specifically, **Perceived Usefulness** demonstrated a **stronger influence** on behavioral intention with a standardized beta coefficient of **β = 0.705**, while **Perceived Ease of Use** also had a meaningful contribution with **β = 0.528**. These findings are consistent with the **Technology Acceptance Model (TAM)**, which suggests that individuals are more likely to adopt and use a technology if they perceive it to be both useful and easy to use. In this context, youth participants are more inclined to engage with digital tools in CBT initiatives when they recognize that such tools can enhance their effectiveness and outcomes in tourism activities. Moreover, the higher beta value for PU suggests that **the perceived benefits of technology in achieving tourism goals (such as income generation, innovation, and cultural promotion)** are more influential in shaping youth behavioral intention than merely the ease with which the technology can be used. This highlights the importance of demonstrating clear value and practical benefits when promoting digital tool adoption among young stakeholders in CBT projects.

5.0 CONCLUSION

This study investigated how youth perceive and use technology in Community-Based Tourism (CBT), focusing on Homestay Kampung Lukut and applying the Technology Acceptance Model (TAM). The findings showed that youth have a high level of perceived usefulness (mean = 4.59) and ease of use (mean = 4.45), indicating they see digital tools as valuable and user-friendly for promoting tourism, generating income, and enhancing cultural experiences. The behavioral intention to use technology was also high (mean = 4.42), showing that most youth are motivated to apply digital platforms in tourism activities. Regression analysis confirmed that both perceived usefulness ($\beta = 0.52$, $p < 0.001$) and perceived ease of use ($\beta = 0.36$, $p = 0.001$) significantly influence behavioral intention, with usefulness having a stronger effect. Despite its contributions, the study faced limitations such as a limited sample size from one location, a one-time data collection, and a focus on only three TAM variables. Still, the research offers valuable theoretical, empirical, and practical insights, especially for policymakers and CBT planners aiming to involve more youth in rural tourism innovation. To strengthen future efforts, the study recommends enhancing digital training, involving youth in CBT planning, improving technology infrastructure, and supporting youth-led initiatives. In conclusion, empowering youth with the right tools and opportunities can drive sustainable tourism development and digital innovation in rural communities.

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Museums in The Digital Era: Strategies for Increasing Visitor Interest Through Technology and Interaction

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ABSTRACT

This research investigates how digital technologies can be used to increase visitor interest in Johor's museums, focusing on tools such as virtual reality, augmented reality, interactive exhibits, and mobile applications. The main question addressed is how these technologies influence visitor engagement, particularly among younger, tech-oriented audiences. The primary aim is to identify effective digital strategies that can modernize the museum experience while preserving cultural heritage. The study is significant as it provides actionable insights for museum professionals seeking to adapt to evolving visitor expectations in the digital era. A quantitative research method was employed using structured questionnaires distributed via Google Forms to museum visitors both online and on-site. The findings indicate that immersive and interactive technologies enhance visitor satisfaction, engagement, and willingness to revisit. However, challenges such as limited funding, lack of technical expertise, and concerns over preserving authenticity were noted as barriers. The study concludes with recommendations for museums to adopt a phased and cost-effective digital transformation strategy, invest in staff training, and collaborate with technology partners. These steps can help ensure museums remain relevant, educational, and engaging in a rapidly changing digital landscape.

Keywords: museums, digital technology, visitor engagement, interactive exhibits, tourism

1.0 INTRODUCTION

Museums actively support tourism and the travel industry, safeguard cultural heritage, and offer educational resources (Shamsidar Ahmad, 2013). Through curated spaces that bring together artifacts, exhibits, and narratives, they allow individuals to connect with the history, art, and culture that shape our collective identity. Museums in Johor are essential in highlighting the area's rich cultural heritage, connecting the past with the present, and deepening cultural appreciation for both locals and visitors. Many museum professionals understand digital media as an opportunity to reach out to a more diverse audience and to increase engagement with museums' collections and topics (Mihelj et al 2019).

As society moves further into the digital age, museums around the world are finding new and innovative ways to adapt to the evolving interests and expectations of their audiences. Many young people today, who are adept with technology and favor interactive and dynamic experiences, might find conventional museum environments less stimulating (Vanessa Cesário 2017). To adapt to these changing preferences, museums are exploring fresh and innovative strategies to enhance visitor involvement, focusing on creating engaging, immersive experiences that can attract a wider range of visitors. (Vincenza, 2013)

In this landscape, digital transformation has become a key focus for museums. This transformation entails incorporating technology into many facets of museum operations, from exhibition displays to the ways information is shared with visitors. Tools like virtual reality (VR), augmented reality (AR), interactive touchscreens, and mobile apps offer museums the

chance to craft personalized, immersive experiences that boost visitor engagement and enrich the educational impact of their exhibits. (Carmen Bachiller 2023)

Many cultural institutions face significant challenges when trying to implement digital technology, despite the advantages it can offer. Factors like restricted funding, insufficient technical skills, and a strong focus on the protection of cultural artifacts often slow down the shift toward modern technology. Furthermore, integrating digital tools goes beyond just upgrading existing equipment; it presents a unique challenge for museums to combine innovation with their core mission. The objective for these institutions is to implement digital enhancements that honor and strengthen their commitment to cultural preservation instead of detracting from it. (Polina Nikolaou 2024)

To address these challenges, this research investigates the opportunities for digital transformation within museums in Johor. A Google Form survey was used to collect feedback from visitors, The survey seeks to uncover effective strategies that can enhance the appeal, accessibility, and engagement of Johor's museums. The outcomes of this research may serve as a valuable resource for museum professionals in Johor, offering guidance on best practices for incorporating technology, which can ultimately enrich the visitor experience and deepen the appreciation of the region's cultural heritage.

1.1 Research Objective

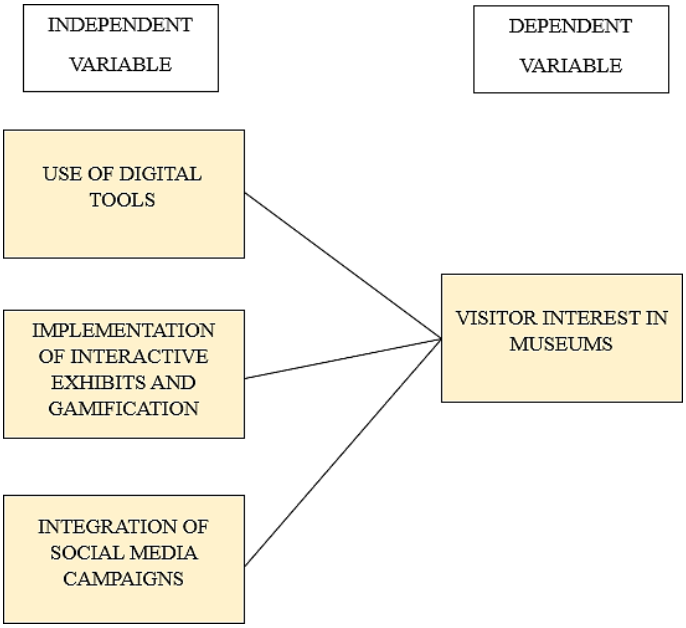
This study aims to explore the potential of digital technologies such as virtual reality (VR), augmented reality (AR), and mobile applications in enhancing visitor interaction and engagement in museum settings. It also seeks to understand visitors' preferences and expectations for interactive and digitally enriched experiences, particularly among younger, tech-savvy audiences. Additionally, the research investigates the challenges and limitations faced by museums in implementing these digital solutions, including issues related to funding, infrastructure, and technical expertise.

1.2 Literature Review

In recent years, museums have shifted from static displays to more interactive and tech-driven experiences to stay relevant and appeal to younger, digital-native audiences. Technology has become a key tool in enhancing visitor engagement, learning, and satisfaction. Tools such as virtual reality (VR), augmented reality (AR), mobile apps, and digital signage enable immersive and personalized experiences that transform traditional exhibitions into dynamic environments (Shamsidar Ahmad, 2013; Vencenza, 2013).

VR allows visitors to explore recreated historical settings or events, while AR overlays digital information on physical exhibits, deepening understanding and interactivity. These technologies also offer solutions for presenting fragile or inaccessible artifacts through digital replicas. Mobile apps further enrich visits by offering guided tours and interactive content, helping museums connect with tech-savvy audiences and bridge the gap between physical and digital engagement.

1.3 Research Framework



2.0 METHODOLOGY

The methodology of this study was designed to investigate how digital technologies such as virtual reality (VR), augmented reality (AR), mobile applications, and interactive exhibits affect visitor engagement in museums across Johor. A quantitative research method was used, focusing on collecting measurable data through structured questionnaires. This approach allows for statistical analysis and helps identify trends and relationships between digital strategies and visitor interest.

2.1 Research Design

This research used a quantitative design, using a structured Google Form questionnaire to gather data. The goal was to explore how digital tools and social media platforms influence engagement, satisfaction, and the likelihood of repeat visits among museum visitors. The survey consisted of multiple-choice and Likert-scale items that targeted specific digital experience indicators. The design allowed researchers to gather a snapshot of visitor behavior and perception during the research period, offering a practical and data-driven approach to understanding digital engagement in cultural settings.

2.2 Data Collection Methods

Data were collected using Google Forms, distributed through one channel: online via social media platforms such as WhatsApp, Telegram, and Tiktok**.** The questionnaire was designed to evaluate:

- Visitor perceptions of digital technologies (VR, AR, mobile apps),
- Interaction with exhibits and gamification,
- Overall satisfaction and loyalty,
- The role of social media in encouraging museum visits.

Responses were anonymous, and data were collected over a four-week period to ensure a sufficient number of participants from various demographic backgrounds.

2.3 Data Analysis

The data were analyzed using descriptive and inferential methods with the help of SPSS and Excel. Key trends and patterns were identified through frequencies and summaries of responses. Since the data were not normally distributed, non-parametric tests were applied. Analysis showed that digital tools and interactive exhibits had a strong influence on visitor interest, while social media showed a weaker connection. Overall, the analysis helped identify which factors most impacted visitors' interest in museums.

3.0 RESULTS AND DISCUSSION

3.1 Respondent

Table 1: Respondent profile

Variable	Category	%
Gender	Female	50.4%
	Male	49.6%
State of Origin	Sarawak	12.0%
	Negeri Sembilan	10.3%
	Johor	7.7%
	Kelantan	8.5%
	Sabah	7.7%
	Kedah / Melaka / KL	6.8% each
	Pahang	5.1%
	Labuan / Perak / Perlis / Penang / Putrajaya / Terengganu	4.3% each
	Selangor	2.6%
Visit Frequency	1 time / Kali pertama	29.1%
	2–5 times	47.0%
	More than 5 times	23.9%

A total of 117 respondents participated in the study. The gender distribution was nearly balanced, with 50.4% female and 49.6% male participants. Respondents came from a wide range of Malaysian states, with the highest representation from Sarawak (12.0%) and Negeri Sembilan (10.3%). The majority had visited a museum 2–5 times (47.0%), while 29.1% were first-time visitors, and 23.9% had visited more than five times. This distribution provides diverse insight into museum visitor experiences in Johor.

3.1 Reliability Analysis

Table 2: Cronbach's Alpha

Construct	Items	Cronbach's Alpha	Interpretation
Overall Scale	13	0.750	Acceptable reliability

A Cronbach's Alpha value of 0.750 shows the questionnaire had good internal consistency. This means the survey items reliably measured visitors' perceptions and behaviors related to digital engagement in museums.

3.2 Descriptive Statistics

Table 3: Descriptive Statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
B1	117	1.00	5.00	3.2735	1.21502
B2	117	1.00	5.00	3.2821	1.36360
B3	117	1.00	5.00	3.1026	1.27566
B4	117	1.00	5.00	3.2393	1.30417
C1	117	1.00	5.00	3.1624	1.35161
C2	117	1.00	5.00	3.1709	1.21974
C3	117	1.00	5.00	3.1197	1.28091
C4	117	1.00	5.00	3.2308	1.30902
C5	117	1.00	5.00	3.3504	1.24787
D1	117	1.00	5.00	2.9744	1.28292
E1	117	1.00	5.00	3.2735	1.12667
E2	117	1.00	5.00	3.3077	1.33560
E3	117	1.00	5.00	3.2906	1.24610
Valid N (listwise)	117				

Among all items, C5 (related to VR/AR experience) had the highest mean score (M = 3.35), suggesting that immersive technologies significantly enhance understanding and interest. D1, a traditionally designed item, had the lowest mean (M = 2.97), reflecting the reduced impact of non-digital methods.

3.3 Research Objective 1

The regression result shows that digital tools significantly and positively affect visitor interest ($\beta = 0.305$, $p < .001$). This supports the idea that technologies such as AR/VR and digital apps make museum experiences more attractive, especially for tech-savvy visitors.

3.4 Research Objective 2

There is a weak but statistically significant positive correlation ($\rho = 0.231$, $p = .012$) between interactivity and visitor interest. This suggests that while interactive exhibits like touchscreens or gamified content contribute to engagement, they are less impactful compared to digital tools like VR/AR.

3.5 Research Objective 3

Social media campaigns have a strong and significant impact on visitor interest ($\beta = 0.487$, $p < .001$). This highlights the importance of using platforms like Instagram, TikTok, or Facebook to promote museums, especially to younger demographics.

3.6 Summary of Findings

Table 4: Summary

Objective	Variable(s)	Test	Result	Support
Objective 1	Digital Tools → Interest	Regression	$\beta = 0.305$, $p < .001$	Supported
Objective 2	Interactivity ↔ Interest	Spearman Correlation	$\rho = 0.231$, $p = .012$	Partially Supported
Objective 3	Social Media → Interest	Regression	$\beta = 0.487$, $p < .001$	Supported

4.0 CONCLUSION

This study explored how digital technology can help museums in Johor attract and engage visitors. The research focused on tools like virtual reality, augmented reality, interactive exhibits, and the use of social media. The findings show that these digital strategies can make museum visits more interesting, especially for younger audiences who prefer interactive and modern experiences. Visitors responded positively to the idea of using technology to make learning more engaging and enjoyable.

However, museums still face challenges such as limited resources, lack of technical skills, and the need to protect the authenticity of their collections. Despite these obstacles, digital innovation remains a valuable opportunity to improve visitor experiences and promote cultural heritage. This study encourages museums to explore creative digital solutions while staying true to their mission. Future research could look into how different types of museums apply these strategies or how visitors' expectations change over time.

In conclusion, technology offers a promising path for museums to stay relevant, connect with wider audiences, and create more meaningful and memorable experiences.

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Online Travel Agents and Repurchase Intention

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ABSTRACT

Digital technology has played a vital role in boosting the popularity of Online Travel Agents (OTAs), as their convenience promotes customer loyalty and repurchase intentions by enhancing brand image, perceived value, and trust. This study investigates the factors influencing repurchase intentions on OTAs platforms, focusing on brand image, perceived value, and trust. The main aim is to understand how these factors affect consumer decisions to repeatedly use OTAs for tourism-related bookings. The study is significant as it contributes to understanding customer loyalty in the competitive and digital-driven tourism industry. A quantitative research method was used, employing online surveys distributed among students, staff and lecturer of Politeknik Ibrahim Sultan. The findings reveal that brand image, perceived value, and trust significantly influence repurchase intention, with trust being the most impactful factor. The study concludes by recommending that OTAs providers enhance service quality, improve brand presentation, and ensure trustworthy online environments to encourage customer retention and repeat bookings.

Keywords: online travel agents, brand image, perceived value, trust, repurchase intention

1.0 INTRODUCTION

1.1 Background of Study

This research looks into why people keep choosing the same Online Travel Agencies (OTAs) for booking their travels. Due to the rise of digital platforms, a lot of people now rely on Agoda, Booking.com and Traveloka for their convenience, range of options and cheap rates. Yet, since there are numerous OTAs, they should know which features convince customers to return. The main purpose of this study is to find out how brand image, perceived value, and trust influence customers' decisions to use the same OTA again. These three factors are believed to play a key role in customer satisfaction and loyalty. A survey was carried out with students, staff and lecturer from Politeknik Ibrahim Sultan who have experienced using OTAs. The collected data were looked at using statistics to determine how much these factors affect repurchase. The results show that all three factors brand image, perceived value, and trust are important, but trust has the strongest impact. This means customers are more likely to return to OTAs they trust. These findings support previous research by Ng et al. (2023), which highlighted the growing importance of trust and value in encouraging repeated OTA usage in Malaysia. Brand image, perceived value, trust, and repurchase intention are key factors that affect how customers choose and stay loyal to Online Travel Agencies (OTAs). When a brand is strong, customers feel more secure and related to the OTA, which increases their chance of booking with the company again (Ng, Yi, & Boon, 2023). At the same time, when prices, convenience, and time saving are valued, customers enjoy the products and become more loyal (Jin, Rahim, & Fong, 2020). Going hand in hand with safety, trust plays a big role for people who exchange their personal and payment data online. Using secure and trustworthy platforms, OTAs attract their customers to return (Hudaya & Chauhan, 2020; Yasa, Giantari, & Dewi, 2020; Rizal, Amin, & Sondoh, 2020). Therefore, customers who have positive views of an OTA as solid

and of high quality will tend to use it for their bookings again (Roslina & Mahrinasari, 2023; Osmani, 2022). Focusing on these elements is essential for OTAs that want to build long-term customer relationships and succeed in the competitive online travel market.

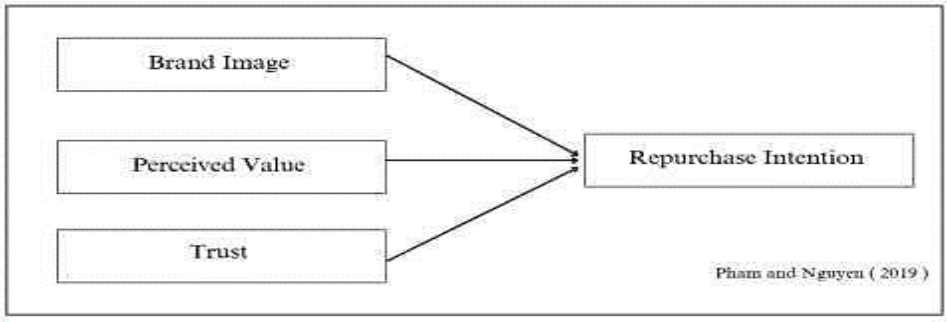

Figure 1: Conceptual Framework

Figure 1 illustrates the conceptual framework adapted from Pham and Nguyen (2019), which examines the influence of brand image, perceived value, and trust on repurchase intention in the context of Online Travel Agencies (OTAs). The model suggests that a strong brand image, higher perceived value, and greater trust can positively impact customers' intention to repurchase. In other words, when customers perceive the OTA as trustworthy, valuable, and reputable, they are more likely to continue using its services in the future.

2.0 METHODOLOGY

This study adopts a quantitative research design to explore how brand image, perceived value, and trust influence consumers' repurchase intention when using Online Travel Agencies (OTAs). A survey-based approach was selected). Because gathering data from many respondents and testing different factors with statistics is possible, the researchers relied on surveys for their approach (Hudaya & Bimaruci, 2020). An explanatory and descriptive design was used to examine how these elements affect people's choices to repurchase the product. Researchers distributed questionnaires to students,staff and lecturer at face to face and on the internet . It was decided that using an online survey would be efficient and inexpensive given that people's consumer behavior is mainly digital these days (Ng et al., 2023).

Both primary and secondary sources were used during the process of collecting data in this study. An online questionnaire was used to collect responses with a 5-point Likert scale so that participants could show their agreement with statements addressing brand image, perceived value, trust, and intent to purchase again (Rizal et al., 2020). Google Forms were distributed face-to-face to students, lecturers, and staff at Politeknik Ibrahim Sultan. In addition, the survey was shared through other platforms such as WhatsApp, TikTok, and Instagram to further increase response rates." Secondary data was taken from various journals, articles, and related writings to help in the analysis and add to the theoretical part of the study (Osmani, 2022). Using more than one data source increases how reliable and true the outcomes are.

Since convenience sampling was accessible and efficient, that method was used (Wee & Anas, 2020). In all, 3,778 people at Politeknik Ibrahim Sultan were targeted in the survey study. The table created by Krejcie and Morgan (1970) suggested that 351 people should be included in the study. There were three parts to the questionnaire: questions about demographics, which

OTA a person prefers, and things that may prompt a repeat purchase, such as brand image, perceived value, and trust. Using this approach, the study finds useful tips for consumers' actions and suggest ways to OTA operators for improving their marketing and motivating customers to stay with them, given the fierce online travel market (Roslina & Mahrinasari, 2023).

3.0 RESULTS AND DISCUSSION

Table 1 displays the details of the demographic profile of the respondents as mentioned in the actual questionnaire. A majority of the study participants were young adults, as 74.3% of them were between 18 and 25 years old. Another age group was composed of 9.3% between 26 and 33, 5.9% between 34 and 41, and 6.8% between 42 and 49, while people aged 50 years and above were 3.7%. More than anything, the respondents possessed either a Degree (51.4%) or a Diploma (45.8%), but few held Master's (2.5%) and the smallest number had a PhD (0.3%). Sixty four percent of respondents take home less than RM2000, but 10.5% earn between RM4000 and RM6000, 13.3% make between RM2000 and RM4000, and 2.2% earn above RM6000.

Table 1: Demography and User of OTA

Variable	Category	Frequency (n)	Percentage (%)
Age	18–25 years	240	74.3%
	26–33 years	30	9.3%
	34–41 years	19	5.9%
	42–49 years	22	6.8%
	50 years and above	12	3.7%
Education Level	Degree	166	51.4%
	Diploma	148	45.8%
	Master	8	2.5%
	PhD	1	0.3%
Monthly Income	Below RM2000	239	74.0%
	RM2000–RM4000	43	13.3%
	RM4000–RM6000	34	10.5%
	Above RM6000	7	2.2%
Use of Online Travel Agents (OTA)	Yes	306	94.7%
	No	17	5.3%
Most Frequently Used OTA	Agoda	149	46.1%
	Airbnb	36	11.1%
	Booking.com	67	20.7%
	Traveloka	35	10.8%
	Trip.com	36	11.1%
Frequency of OTA Usage	1–2 times	149	46.1%
	3–4 times	114	35.3%
	Rarely	60	18.6%

Almost everyone surveyed, 94.7%, had used Online Travel Agents (OTAs), proving that people are very familiar with these services. When surveyed, most people said they often choose Agoda (46.1%), then Booking.com (20.7%), Airbnb (11.1%), Trip.com (11.1%), and Traveloka (10.8%). 46.1% said they book through online travel agencies one to two times. Thirty-five percent mentioned that they do so three to four times, and 18.6% said they rarely go this route. It is clear from these findings that OTAs are favored by young, well-educated people with lower income, which is in line with what is currently happening in digital Malaysian travel (Ng et al., 2023).

3.1 Tables and Figures

The reliability test results show that all parts of the questionnaire are consistent and reliable. This was measured using Cronbach's Alpha, a number that tells us how well the questions in each section work together. A value above 0.70 is considered good, and values above 0.90 are excellent. For Brand Image**,** the Cronbach's Alpha is 0.912, which means the questions in this section are very consistent and reliable. Respondents answered these questions in a similar way, showing that they measure the same idea well. For Perceived Value, the value is 0.895**,** which also shows strong consistency. This means the questions about how useful and valuable OTAs are were answered in a reliable way. The Trust section has a Cronbach's Alpha of 0.897, showing that the questions about feeling safe and trusting the information given by OTAs are also very reliable. Repurchase Intention has a Cronbach's Alpha of **0.857**, which is still considered good. This means the questions about whether people plan to keep using OTAs are reliable too. The Overall Questionnaire, which includes all 15 items, has a Cronbach's Alpha of **0**.974**,** which is excellent. This shows that the whole questionnaire is very reliable and the results can be trusted. In conclusion, all sections of the questionnaire are reliable and consistent. This means the data collected from respondents is trustworthy for this research.

Table 2: Cronbach's Alpha Each Items

Variable	Items	Cronbach's Alpha
Brand Image	The OTA I often use is a well-known brand. A trusted OTA gives me confidence when booking. I prefer booking with OTAs that have long-established existence. An OTA's reputation affects my booking decisions.	**0.912**
Perceived Value	OTAs help me book faster than traditional agencies. OTAs help me spend less on travel bookings. I find it easy to compare travel options on OTAs. OTAs provide detailed information.	**0.895**
Trust	I feel safe making payments on OTAs. I trust OTAs to give accurate information. I trust OTAs to handle complaints fairly and efficiently. I trust OTAs' clear refund and cancellation policies.	**0.897**
Repurchase Intention	Brand Image Perceived Value Trust	**0.857**
Overall Questionnaire	All variables combined (Brand Image, Perceived Value, Trust, Repurchase Intention, etc.) Total of 15 items	**0.974**

The table 3, the reliability analysis using Cronbach's Alpha demonstrates that all sections of the questionnaire exhibit good to excellent internal consistency, with alpha values exceeding 0.85. This indicates that the items within each section are highly correlated and consistently measure their respective constructs. The high overall alpha value of 0.974 confirms that the questionnaire is a reliable instrument for data collection in this study. With strong reliability established, the research can confidently proceed to further data analysis stages.

Table 3: Reliability Test

VARIABLES	NUMBER OF ITEMS	CRONBACH'S ALPHA VALUE	LEVEL OF STRENGTH
Brand Image	4	0.912	Excellent
Perceived Value	4	0.895	Good
Trust	4	0.897	Good
Repurchase Intention	3	0.857	Good
Overall Questionnaire	**15**	**0.974**	**Excellent**

The Spearman correlation table shows strong positive relationships between all the variables: Brand Image, Perceived Value, Trust, and Repurchase Intention. All correlations are statistically significant at the 0.01 level, which means the results are reliable. Brand Image is strongly related to Trust (r = 0.867) and Perceived Value (r = 0.852), showing that when people see an OTA as reputable, they are more likely to trust it and see value in it. Perceived Value has the strongest correlation with Repurchase Intention (r = 0.886), meaning that if users feel they are getting good value, they are more likely to use the OTA again. Trust also shows a strong link to Repurchase Intention (r = 0.846), indicating that trust plays a key role in customer loyalty. Overall, the table confirms that a good brand image, strong perceived value, and high trust levels all significantly increase the chances of customers repurchasing from the same OTA.

Table 4: Correlation Construct

CONSTRUCTS	BRAND IMAGE	PERCEIVEDVAL UE	TRUST	RPI
BRAND IMAGE	1	0.852**	0.867**	0.816**
PERCEIVED VALUE	0.852**	1	0.868**	0.886**
TRUST	0.867**	0.868**	1	0.846**

4.0 CONCLUSION

In conclusion, this study showed that brand image**,** perceived value**,** and trust all have a strong influence on repurchase intention among users of Online Travel Agents (OTAs) at Politeknik Ibrahim Sultan. The results from the Spearman correlation analysis confirmed that these three factors are closely related and help build customer loyalty. Among the three**,** trust and perceived value were the most important. This means that customers are more likely to book again through OTAs they trust and feel give them good value. These findings support previous research by Ng et al. (2023), which also found that trust and value are key to keeping customers coming back to OTA platforms. This study gives useful insights to OTA companies. To increase repurchase intention, they should focus on building trust, improving the customer experience, and showing the value of their services. By doing this, OTAs can attract repeat customers and stay competitive in the online travel market.

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Preserving Cultural Heritage Through Traditional Dance: A Study of Zapin in Johor

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ABSTRACT

Zapin is a traditional Malay dance with historical roots in Arab culture, widely practiced in Johor, Malaysia, and celebrated for its role in expressing cultural identity and values. Over time, it has evolved into a community-based performance art that integrates choreography, traditional attire, and music reflective of Malay-Islamic heritage. However, the growing influence of modernization and diminishing public engagement-particularly among younger generations-pose significant threats to its continuity. This study explores the role of Zapin in preserving Johor's cultural heritage by examining public perceptions of its three core elements: choreographic structure, traditional costume, and musical composition. A quantitative research design was employed, involving 400 respondents from various districts in Johor, with data collected via structured questionnaires measuring awareness and appreciation of Zapin. Findings indicate that all three elements are perceived as integral to cultural preservation. Choreography is seen to embody Malay philosophical values of moderation and harmony; traditional costumes symbolize modesty and cultural identity; and the music is recognized for its distinctive blend of Malay and Arabic influences. This research offers a data-driven, community-focused perspective on heritage arts, an area often underrepresented in academic discourse. The study provides practical implications for policymakers, educators, and cultural practitioners in sustaining and revitalizing Zapin through education, performance, and community initiatives. Ultimately, the findings reaffirm Zapin's significance as both a historical artifact and a living tradition essential to the cultural sustainability of Johor.

Keywords: *zapin* dance, traditional Malay dance, cultural heritage, local heritage

1.0 INTRODUCTION

Zapin is a traditional Malay dance form that traces its origins to Hadharamaut, Yemen, introduced to Southeast Asia through Arab traders as part of their commercial and religious exchanges (Hamza, 2023; Fuaddah, Yahya, & Istiandini, 2020). Over time, Zapin has evolved into a deeply rooted element of Malay and Malay-Arab cultural identity, especially in Johor, Malaysia. Initially performed exclusively by men for religious purposes, it has since broadened its scope, now including both male and female performers and serving both ceremonial and entertainment functions (Mustaffa & Idris, 2017).

In Johor, Zapin has undergone a unique process of localization and adaptation. Unlike other regions where court patronage played a significant role, Zapin in Johor has remained a community-based performance deeply embedded in local traditions and Islamic aesthetics (Jalur Gemilang, 2023; Nor, 1993). As noted by Prof. Mohd Anis Md Nor, its development outside the sphere of royal influence underscores its grassroots origins and enduring cultural relevance. He highlights its distinctive features embodiment of Malay culture, Islamic values, and gender-based performance norms as key to its uniqueness and sustained popularity, even in mosque settings (Mohd Anis Md Nor, interview 2021).

In addition, the structure of Zapin performances in Johor reflects a delicate balance of tradition and innovation. Two principal forms Main Zapin, characterized by improvisation and spontaneity, and Tarian Zapin, known for its choreographic precision demonstrate the genre's adaptability and its dual role as both a communal activity and formal presentation (Hamza, 2023). This adaptability is evident in the regional variation Zapin Tengliu, originating from Mersing, which showcases the localized evolution of the art form (Jalur Gemilang, 2023).

However, the continued relevance of Zapin is now at risk due to the effects of modernization, globalization, and changing societal interests, particularly among younger generations. Deviations in choreography, costume, and music threaten the authenticity of the dance, while a lack of comprehensive documentation and promotional efforts has led to declining public awareness and appreciation. These challenges underscore the need to preserve and revitalize the Zapin tradition to ensure it remains a meaningful symbol of Johor's cultural identity (Hafzan Zannie Hamza,2023).

This study aims to explore how the key elements of Zapin its choreography, traditional costumes, and musical components reflect and preserve Johor's local cultural heritage. By examining these aspects, the research provides valuable insight into how Zapin continues to influence cultural identity in the region. Furthermore, the study contributes to cultural preservation efforts by documenting the artistic and symbolic elements of the dance, strengthening community pride, and fostering renewed interest among younger generations. In doing so, it seeks to ensure that Zapin remains a vibrant and enduring tradition within Johor's cultural landscape.

2.0 METHODOLOGY

This study employed a quantitative research methodology to investigate the preservation of the Zapin dance as an element of cultural heritage in Johor. The methodology outlines the research design, data collection methods, research instruments, and sampling design, all of which were chosen to ensure the reliability and validity of the findings.

A structured questionnaire served as the primary research instrument, designed to collect data on respondents' demographic profiles and their perceptions of key components of Zapin namely choreography, costume, and music. The questionnaire included a combination of Likert-scale and multiple-choice items to ensure comprehensive and measurable responses. To enhance the instrument's reliability and clarity, a pilot test was conducted with selected members from cultural organizations such as PE-Zapin and PERZIM.

Primary data were collected from 400 respondents across various districts in Johor, comprising individuals from the general community with knowledge or exposure to Zapin. These included performers, musicians, and cultural enthusiasts. The sample size exceeded the recommended 384 respondents based on Krejcie and Morgan's (1970) sample size table, strengthening the validity of the study. A random sampling technique was applied to ensure that every eligible participant had an equal opportunity to be included, thereby reducing selection bias and increasing the generalizability of the results.

In addition to primary data, secondary data were gathered from academic journals, official reports, and previous studies relevant to traditional dance and cultural heritage preservation.

These sources provided essential context and supported the formulation of research objectives and questions.

This methodological framework ensures a rigorous and systematic approach to examining public perceptions toward the cultural preservation of the Zapin dance in Johor.

3.0 RESULT AND DISCUSSION

This section presents the findings derived from data collected through a structured questionnaire aimed at addressing the study's research objectives. The analysis begins with a 100% response rate from all 400 distributed questionnaires, with no missing data, indicating strong respondent engagement and enhancing the reliability and generalizability of the findings. Demographic profiling was conducted to understand the respondents' backgrounds, followed by reliability analysis using Cronbach's Alpha to assess the internal consistency of questionnaire items. Descriptive statistics, including means and standard deviations, were used to summarize responses, while Spearman correlation analysis examined the strength and direction of relationships between key variables. These analyses provide a robust empirical basis for interpreting the results and forming the study's CONCLUSION.

3.1 Tables and Figures

Table 1: Demographic Analysis

Gender			
		Frequency	Percent (%)
Valid	Female	217	54.25
	Male	183	45.75
Age			
Valid	18 - 25 years	186	46.5
	26 - 35 years	97	24.25
	36 - 45 years	45	11.25
	46 - 55 years	43	10.75
	Above 56 years	29	7.25
Race			
Valid	Malay	233	58.25
	Chinese	66	16.5
	Indian	63	15.75
	Others	38	9.5
Occupation			
Valid	Government Sector	59	14.75
	Private Sector	153	38.25
	Student	188	47.0
Nationality			
Valid	Malaysian	365	91.25
	Non- Malaysian	35	8.75

Based on Table 1, the dataset of this study's findings encompasses a sample size (n=400) of respondents, providing insight into the demographic composition within this surveyed population. Gender distribution indicated a higher proportion of females (n= 217, 54.25%) compare to males (n= 183, 45.75%). Age distribution indicates that the majority were aged 18 to 25 years (n=186, 46.5%) and the lowest distributes were age above 56 years (n= 29, 7.25%). Meanwhile, for race, the most respondents were identified as Malay (n = 233,58.25%) and the least respondents were Other (n = 38, 9.5%). Regarding the occupation, students formed the largest group (n = 188, 47%) and the smallest group were government sector (n=59, 14.75%). Lastly, the nationality data showed that the majority of respondents were Malaysian (n = 365, 91.25%) with a minority being non-Malaysia (n = 35, 8.75%).

Table 2: Correlation Analysis

Correlations					
					HYPOTHESIS
Spearman's rho	Semua	Correlation Coefficient	1.000	.833**	SUPPORTED
		Sig. (2-tailed)	.	<.001	
		N	400	400	
	Choreography	Correlation Coefficient	.833**	1.000	
		Sig. (2-tailed)	<.001	.	
		N	400	400	
Spearman's rho	Semua	Correlation Coefficient	1.000	.921	SUPPORTED
		Sig. (2-tailed)	.	<.001	
		N	400	400	
	Costume	Correlation Coefficient	.921	1.000	
		Sig. (2-tailed)	<.001	.	
		N	400	400	
Spearman's rho	Semua	Correlation Coefficient	1.000	.949*	SUPPORTED
		Sig. (2-tailed)	.	<.001	
		N	400	400	
	Music	Correlation Coefficient	.949*	1.000	
		Sig. (2-tailed)	<.001	.	
		N	400	400	

A Spearman' Rho correlation analysis is a non-parametric statistical method used to measure the strength and direction of association between two variables. Unlike Pearson correlation, which assesses linear relationships, Spearman' Rho correlation evaluates how well the relationship between two variables can be described using a monotonic function (as one variable increases, the other tends to either increase or decrease consistently).

Based on Table 2, a Spearman' Rho correlation analysis was conducted to examine the relationship between all variables and choreography. The results revealed a strong and statistically significant positive correlation between these variables (r =.833, p=<.001). It also shows that Spearman' Rho correlation analysis was conducted to examine the relationship between all variables and costume. The results revealed a strong and statistically significant positive correlation between these variables (r =.921, p=<.001) and Spearman' Rho correlation analysis was conducted to examine the relationship between all variables and music. The results revealed a strong and statistically significant positive correlation between these variables (r =.949, p=<.001). Overall, the results show that all variables under study are positively and strongly linked to the core components of Zapin, highlighting their collective importance in sustaining the cultural heritage of Zapin dance in Johor.

4.0 CONCLUSION

This study has explored the cultural and social significance of Zapin dance in Johor, focusing on its key elements choreography, costume, and music as essential components in the preservation of cultural heritage. Originally introduced from Hadharamaut through Arab traders, Zapin has evolved from a religious, male-only performance into an inclusive and dynamic traditional art form that reflects a fusion of Arab and Malay cultural influences. The dance has transcended its ceremonial origins to become an integral part of community life in Johor, performed both formally at weddings and informally in local villages, reinforcing social cohesion and regional identity (Mustaffa, N. & Idris, M. Z. 2017).

The study's findings highlight the importance of choreography, costumes, and music in sustaining the cultural relevance of Zapin. Each element plays a significant role in expressing the historical and aesthetic values embedded within the tradition. The reliability analysis using an 18-item questionnaire demonstrated excellent internal consistency (Cronbach's Alpha = 0.977), confirming that the instrument effectively measures all four constructs. Moreover, Spearman's Rho correlation analysis revealed strong and statistically significant positive relationships between the variables and the core components: choreography (r = .833), costume (r = .921), and music (r = .949), all with p-values < .001. These results collectively emphasize the interconnections and importance of these elements in maintaining the vibrancy and authenticity of Zapin as a traditional Malay performing art.

For future research, it is recommended to explore comparative studies across different regions to examine how Zapin varies in style and practice, thereby highlighting its adaptability and regional uniqueness. Researchers could also investigate intergenerational perspectives to understand how younger generations engage with and perceive Zapin, especially in the context of digital media. Additionally, evaluating the integration of Zapin into educational programs may provide insights into its role in fostering cultural appreciation among youth. In- depth ethnographic studies in active Zapin communities could uncover deeper cultural meanings and performance dynamics, while analyses of the impacts of modernization and globalization could reveal current challenges and opportunities for cultural preservation. These suggested directions would enrich the understanding of Zapin and support ongoing efforts to safeguard it as an important element of Malaysia's intangible cultural heritage.

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The Development of Halal Gastronomy from A Tourism Perspective: A Case Study of Pasir Gudang, Johor Malaysia

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ABSTRACT

Halal gastronomy, which encompasses food prepared in accordance with Islamic dietary laws, is an emerging and significant segment within the global tourism industry, reflecting rising demand from both Muslim and non-Muslim consumers. This study examines the development of halal gastronomy in Pasir Gudang from a tourism perspective, with the objective of identifying key factors that influence its growth and acceptance. Utilizing a quantitative research approach, data were collected through structured surveys administered to 385 respondents representing diverse demographic backgrounds. The analysis explored the relationships among halal food quality, production practices, certification, and the overall advancement of halal gastronomy. The findings underscore the pivotal role of halal certification in driving the growth of halal gastronomy tourism, while food quality and production factors were found to have varying impacts. These insights carry significant implications for policymakers, industry stakeholders, and tourism practitioners, highlighting the need to strengthen certification frameworks, enhance production standards, and develop targeted strategies to effectively promote halal gastronomy. The study concludes with recommendations to support sustainable growth and position Pasir Gudang as a prominent destination in the halal tourism market.

Keywords: halal gastronomy, halal food quality, halal food production, halal certification

1.0 INTRODUCTION

1.1 Introduction

Halal gastronomy tourism is becoming an important part of the global tourism industry, driven by the fast-growing Muslim travel market. According to the State of the Global Islamic Economy Report 2022, this market is expected to reach USD 225 billion by 2028. Since food is a key part of any travel experience, halal gastronomy which follows Islamic rules of halal and toyyib has a big influence on Muslim tourists' satisfaction and destination choices. Malaysia has long been a top Muslim-friendly destination, known for its strong halal system and diverse food culture. In Johor, Pasir Gudang has good potential to grow as a halal gastronomy hub because of its rich local food, culture, and its location near Singapore, which attracts many international visitors.

Several factors help the growth of halal gastronomy tourism, such as food quality, cleanliness, safety, authenticity, and clear food preparation processes. Tourists also look for transparent ingredient sourcing and varied halal menu choices. Malaysia's halal certification by JAKIM is well-known globally and helps build trust, but it needs to be applied consistently and promoted well to tourists.

Because of this, the study aims to explore what factors influence the development of halal gastronomy tourism in Pasir Gudang. It also hopes to suggest ways for local authorities, tourism players, and businesses to improve and position Pasir Gudang as a leading halal food tourism spot.

1.2 Research Objective

This study is conducted with three main objectives. Firstly, it aims to explore the current development of halal gastronomy in Pasir Gudang, focusing on how the local food scene has adapted to meet the growing demand for halal-compliant dining experiences.

Secondly, the study seeks to analyze the role of halal food in enhancing tourism in Pasir Gudang, examining how halal food availability and standards influence tourist satisfaction, attract Muslim travelers, and contribute to the region's tourism appeal.

Lastly, the research aims to identify the key challenges and potential opportunities in promoting halal gastronomy within the area. This includes understanding operational issues, market gaps, and strategic advantages that could help position Pasir Gudang as a recognized halal gastronomy destination in Johor and Malaysia.

1.3 Research Question

This study is guided by three key research questions. Firstly, it investigates how halal gastronomy has developed as an important tourism segment in Pasir Gudang, Johor, exploring the growth and progress of halal food services and how they contribute to the tourism industry in the region.

Secondly, the study seeks to understand how halal food influences the tourism experience and attracts visitors to Pasir Gudang. This question focuses on how the availability, quality, and authenticity of halal food impact tourist satisfaction, travel decisions, and the overall tourism appeal of the destination.

Lastly, the research aims to identify the challenges and opportunities in promoting halal gastronomy tourism within Pasir Gudang. This involves examining existing problems such as food quality consistency and certification, while also exploring future opportunities like marketing initiatives, culinary events, and infrastructure improvements to strengthen Pasir Gudang's position as a halal gastronomy destination**.**

1.4 Conceptual Framework

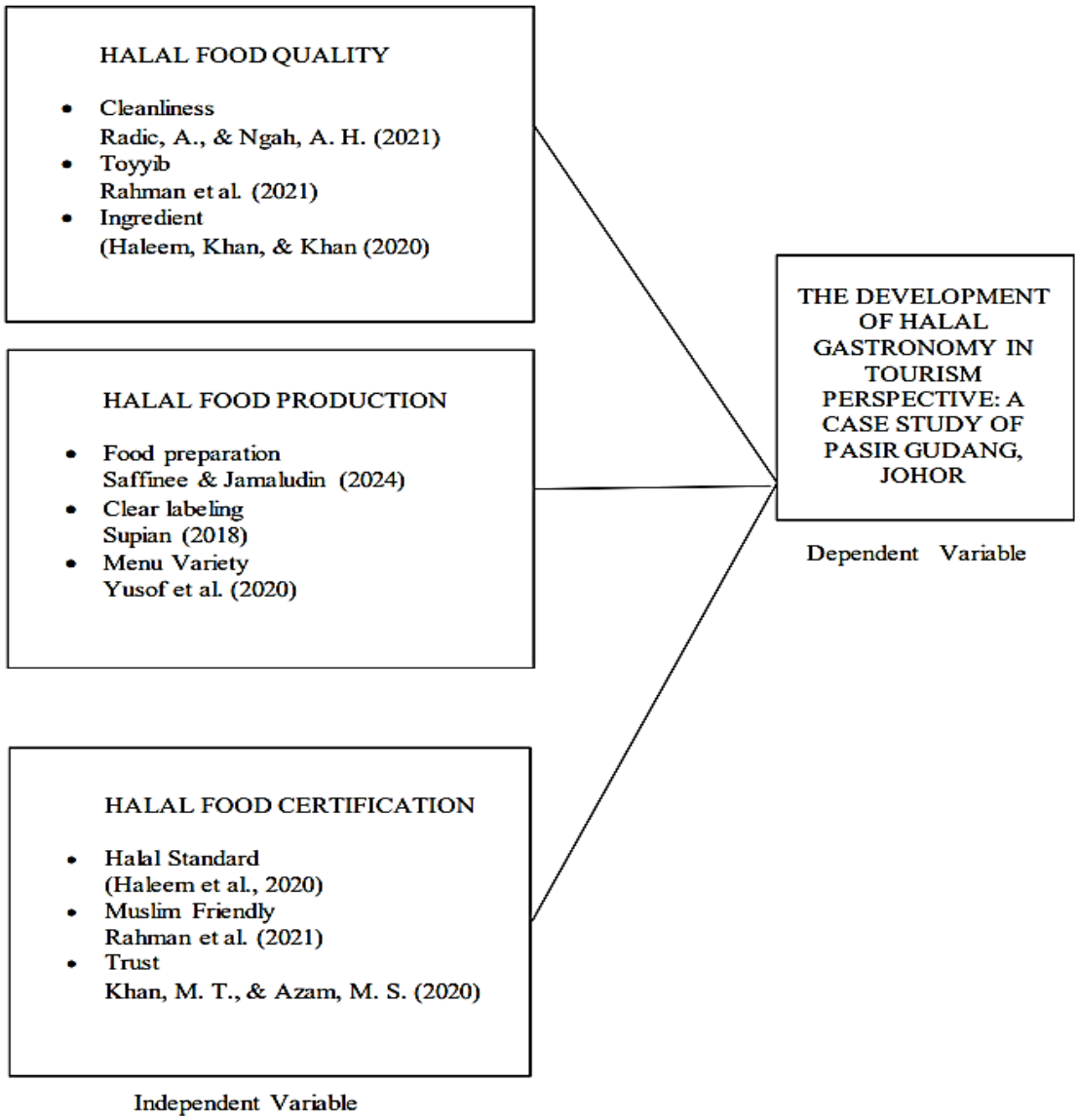

Figure 1: Conceptual Framework

2.0 METHODOLOGY

This study adopts a quantitative research methodology as the foundation to achieve its research objectives. It focuses on examining the impact of three essential factors halal food quality, halal food production, and halal certification on the development of halal gastronomy tourism in Pasir Gudang.

A structured survey questionnaire was used to collect primary data from consumers, providing measurable and standardized information on their perceptions and experiences. This approach was chosen to ensure that the findings are reliable, valid, and statistically analyzable, accurately reflecting the current state of halal gastronomy in the region.

By applying a systematic and data-driven methodology, the study aims to contribute meaningful insights to the broader understanding of how halal gastronomy supports tourism growth, while offering valuable recommendations for improving halal tourism services in Pasir Gudang.

2.1 Research Design

This study adopts a quantitative research method to provide a structured and measurable understanding of the development of halal gastronomy from a tourism perspective in Pasir Gudang. The quantitative approach enables the collection and statistical analysis of data related to consumer perceptions, market trends, and other measurable factors influencing halal gastronomy. This method allows for objective evaluation and generalization of findings to support evidence-based conclusion in the development halal gastronomy sector.

2.2 Data Collection Method

This study will collect primary quantitative data to understand the development of halal gastronomy in Pasir Gudang. Structured surveys will be used to gather consumer perceptions on halal food quality, production, and certification. The survey will focus on factors like cleanliness, Toyyib principles, food preparation, labeling, and trust in halal certification. It will be distributed to both Muslim and non-Muslim consumers to capture a broad range of views. Responses will be measured using a 5-point Likert scale for statistical analysis of customer preferences. Additionally, secondary data from academic sources, industry reports, and government publications will complement the primary data, providing a well-rounded analysis of halal gastronomy in the tourism sector.

2.3 Sampling

Sampling is important to ensure relevant data is collected from halal food consumers in Pasir Gudang. A stratified random sampling method will be used to select participants from different demographic groups such as age, gender, religion, and nationality. This will ensure a diverse and representative sample for analyzing halal gastronomy in tourism.

The sample will include different age, gender, and nationality groups, to capture a wide range of consumer experiences. A minimum of 384 respondents will be targeted, based on the Krejcie and Morgan table, ensuring statistical reliability and sufficient power for analysis.

The study will focus on collecting numerical data through structured surveys, with the sampling method ensuring a representative group to reflect consumer perceptions of halal gastronomy and its role in tourism in Pasir Gudang.

2.4 Research Instrument

The questionnaire will be divided into sections focusing on halal food quality, production, and certification. Each section will contain closed-ended questions using a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree," allowing for statistical analysis of respondents' attitudes and perceptions:

- Section A: Demographic
- Section B: Halal food quality
- Section C: Halal food production
- Section D: Halal food certification
- Section E: The development of halal gastronomy

The questionnaire will be distributed via Google Forms to facilitate easy and efficient data collection.

2.5 Data Analysis Method

SPSS was selected as the primary tool for data analysis due to its robust capabilities in handling large datasets and performing various statistical procedures. It is widely used in academic research for its ease of use and comprehensive range of statistical tests, capable of handling both descriptive and inferential statistics. SPSS's powerful tools enable efficient data management, manipulation, and interpretation, making it ideal for analyzing survey data collected from respondents. The analysis aims to explore how food quality, food production, and halal certification influence halal gastronomy tourism in Pasir Gudang, helping to identify the most significant factors impacting tourism development and providing evidence-based recommendations for stakeholders in the halal tourism sector.

The data for this study was gathered through a structured questionnaire, administered to 385 respondents. The questionnaire included both demographic questions and perception-based statements regarding food quality, food production, and halal certification, divided into five sections. Section A covered demographic information, such as age, gender, nationality, occupation, frequency of visits to Pasir Gudang, and familiarity with halal food, providing context for understanding factors that influence perceptions of halal gastronomy. Section B focused on food quality, addressing respondents' views on cleanliness, halal certification of ingredients, and satisfaction with halal food in Pasir Gudang. Section C examined food production, asking about labeling, transparency in food preparation, and the variety of halal food options. Section D explored halal certification, looking at its importance, trustworthiness, and the confidence in halal certification within Pasir Gudang. Finally, Section E assessed respondents' perceptions of the development, importance, and opportunities of halal gastronomy tourism in Pasir Gudang.

3.0 RESULT AND DISCUSSION

The data for this study was collected from 385 respondents using a structured questionnaire, which aimed to capture their perceptions of halal gastronomy in Pasir Gudang, Johor. The respondents were primarily young, with the largest group aged 18-24 years, followed by 35-44 years. The sample included a higher proportion of male respondents (56.6%) and was predominantly composed of students (53.5%). Most respondents were familiar with halal food, which reflects the region's established halal food practices.

For data analysis, SPSS (Statistical Package for the Social Sciences) was chosen due to its powerful capabilities in handling large datasets and performing a wide range of statistical procedures. The analysis included both descriptive and inferential statistics to explore the key factors influencing halal gastronomy tourism. Specifically, descriptive statistics were used to analyze the responses to demographic questions, food quality, food production, and halal certification.

A reliability test was conducted using Cronbach's Alpha, which yielded a value of 0.712, indicating that the survey instrument was reliable for capturing respondents' attitudes and perceptions. Furthermore, normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) revealed that the data did not follow a normal distribution, suggesting the use of non-parametric tests

for further analysis.

Regression analysis was also performed to test the research hypotheses. The results indicated that halal food certification had a strong positive relationship with the development of halal gastronomy tourism, while food quality and food production showed less significant impacts. The regression analysis helped determine which factors were most influential in the development of halal gastronomy tourism in Pasir Gudang, providing valuable insights for stakeholders in the tourism and food sectors.

The methodology used in this study was primarily quantitative, with a focus on structured surveys and statistical analysis to ensure reliable and valid results. This approach allowed for the collection of measurable data, which was crucial for understanding the factors affecting halal gastronomy tourism and for providing evidence-based recommendations for further development in Pasir Gudang.

Table 1: Descriptive Analysis

Variable	Mean Per Variable	Mean	Std. Deviation
Quality	4.5631	4.5566	0.19419
Production	4.6182		
Certification	4.5517		
Development	4.4935		

The table 1 show the mean values of four key variables related to the development of halal gastronomy tourism in Pasir Gudang, Johor. These variables are food quality, food production, halal certification, and the overall development of halal gastronomy. The results from 385 respondents show that halal food production received the highest mean score of 4.6182, indicating strong agreement among respondents about the importance of food production in enhancing halal gastronomy. Following this, halal food quality also scored highly, with a mean value of 4.5631, suggesting that cleanliness, ingredient authenticity, and overall food quality are crucial factors influencing halal gastronomy perceptions. Halal food certification received a mean score of 4.5517, indicating that respondents view certification as an essential factor in building trust and ensuring food authenticity.

The overall development of halal gastronomy in Pasir Gudang, as reported by the respondents, scored 4.4935, suggesting a generally positive outlook on the region's progress in halal gastronomy tourism. The study's findings also highlight low standard deviations across all variables, indicating that respondents' views were consistent and that there is strong agreement regarding the importance of these factors in the development of halal gastronomy. These insights suggest that Pasir Gudang is perceived positively in terms of halal gastronomy, with significant areas to improve in food production, quality, and certification practices to further strengthen its position as a halal gastronomy tourism hub.

3.1 Regression Analysis

Table 2 show regression analysis reveals mixed results regarding the factors influencing the development of halal gastronomy in Pasir Gudang. First, the hypothesis that halal food quality significantly influences the development of halal gastronomy was not supported. The analysis showed a negative relationship (Std. Beta = -0.342) with a t-value of -7.345, suggesting that improving food quality alone may not directly contribute to the growth of halal gastronomy in the region. While food quality remains important, other factors such as food presentation, menu innovation, and cultural integration may be necessary to stimulate tourism.

Table 2: Regression Analysis

Hypothesis	Std. Beta	Std. Error	t-value	Decision
HALAL FOOD QUALITY	-0.342	0.046	-7.345	Not Supported
HALAL FOOD PRODUCTION	-0.186	0.050	-3.697	Supported
HALAL FOOD CERTIFICATION	0.462	0.055	10.206	Supported

On the other hand, halal food production was found to have a small but significant impact on tourism in Pasir Gudang (Std. Beta = -0.186, t-value = -3.697). Although the relationship between food production and tourism development is not very strong, it still plays an essential role in influencing tourist satisfaction. Key aspects such as food labeling, transparency in food preparation, and a variety of halal food options contribute to building trust and meeting the expectations of halal-conscious tourists.

Lastly, halal food certification emerged as the most significant predictor of halal gastronomy development in the region. The analysis revealed a strong positive relationship (Std. Beta = 0.462, t-value = 10.206), indicating that official certification plays a critical role in enhancing the region's halal tourism. Halal certification builds consumer trust, assures food authenticity, and strengthens the destination's credibility. This makes certification the most influential factor in promoting halal gastronomy tourism in Pasir Gudang, demonstrating that certified halal food offerings are essential for attracting Muslim tourists.

4.0 CONCLUSION

In conclusion, this study successfully examined the factors influencing the development of halal gastronomy tourism in Pasir Gudang, Johor. The findings indicate that while food quality alone may not directly stimulate tourism growth, consistent halal food production and credible halal certification are crucial in enhancing the region's gastronomic appeal. Notably, halal certification emerged as the most significant factor in fostering tourist trust, satisfaction, and destination loyalty within the halal tourism market.

Additionally, the results revealed that consumers in Pasir Gudang highly value operational transparency, food safety, and visible halal certification, all of which contribute to shaping their halal dining experiences. This research contributes to the growing body of knowledge on halal gastronomy and provides actionable insights for local policymakers, tourism authorities, and food service operators to improve their halal offerings.

Looking ahead, adopting a comprehensive strategy that emphasizes the enforcement of certification, the standardization of food production, and the development of innovative culinary tourism experiences will position Pasir Gudang as a leading halal gastronomy destination in Malaysia. With sustained efforts, the region holds the potential to significantly contribute to Malaysia's aspiration of becoming a global leader in halal tourism, while simultaneously fostering economic growth and cultural diversity within the local community.

4.1 Discussion

This study examined the factors influencing halal gastronomy tourism in Pasir Gudang, focusing on food quality, production, and certification. While food quality is important, it alone may not boost tourism without factors like presentation and menu innovation. Halal food production, including clear labeling and transparency, was found to significantly impact tourism by building trust. The most important factor, however, was halal certification, which plays a crucial role in establishing trust and credibility, making Pasir Gudang a reliable halal gastronomy destination.

4.2 Recommendations

Recommendations for Pasir Gudang's halal gastronomy tourism include improving the dining experience by enhancing food presentation and incorporating local culture. Authorities should standardize halal food production through training and clear guidelines. Strengthening the halal certification system with better awareness and enforcement will build trust. Lastly, marketing efforts should promote Pasir Gudang as a halal gastronomy hub, attracting both Muslim and non-Muslim tourists to boost the local economy.

4.3 Limitations

This study has some limitations. First, it relied solely on quantitative data from structured questionnaires, which may limit the depth of insights. A mixed-method approach, including interviews or focus groups, could have provided more detailed perspectives. Second, the study focused only on consumers in Pasir Gudang, which may limit the ability to generalize the findings to other regions. Future research should include comparative studies across multiple halal tourism destinations. Lastly, the study mainly involved younger respondents, especially students, so future studies should include a more diverse sample across age groups and occupations to get a broader view of consumer perceptions.

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The Effect of Service Quality on Tourist Loyalty towards Budget Hotels in Malaysia

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ABSTRACT

This study investigates the influence of key service quality dimensions responsiveness, reliability, and tangibility on tourist loyalty at Malaysia budget hotels. The main objective is to assess how these factors affect guests' intentions to revisit and recommend the hotels to others. As budget hotels in Malaysia face increasing competition and cater to a growing segment of value-conscious travelers, understanding what drives customer loyalty is essential for their long-term success. A quantitative research design was employed, using structured questionnaires to collect data from tourists who had stayed in budget hotels across different regions of Malaysia. The survey captured guest perceptions of service quality and their likelihood of returning or promoting the hotel based on their experience. The results reveal that reliability and responsiveness significantly influence tourist loyalty, suggesting that consistent and prompt service delivery plays a vital role in guest satisfaction. Tangibility, which refers to the physical appearance and facilities of the hotel, showed a lesser but still relevant impact. The study concludes by recommending that Malaysia budget hotels to focus on improving staff performance, service consistency, and customer interaction to strengthen loyalty. These findings offer practical insights for hotel operators and contribute to the broader understanding of service quality in the budget hospitality sector.

Keywords: service quality, customer satisfaction, budget hotels, hospitality industry

1.0 INTRODUCTION

Tourism has long been a key pillar of Malaysia's economic development, contributing significantly to the nation's Gross Domestic Product (GDP) and employment. Within this landscape, budget hotels serve as an essential component by offering affordable and accessible accommodation to a diverse range of travelers. Their role is especially important in supporting Malaysia's goal of being a competitive and welcoming destination in Southeast Asia. As the hospitality industry evolves, so do the expectations of modern travelers. Even within the budget segment, guests now seek not only affordability but also quality service, comfort, and personalized experiences. This shift has placed pressure on budget hotels to improve service delivery and overall customer experience. While much research has been conducted on service quality and customer satisfaction in luxury accommodations, limited attention has been given to customer loyalty in budget hotels, particularly in the Malaysian context. This study addresses that gap by examining how different aspects of service quality influence customer loyalty in Malaysia's budget hotel sector. Understanding these relationships can help hotel operators develop more effective strategies to retain guests and improve competitiveness in an increasingly demanding market.

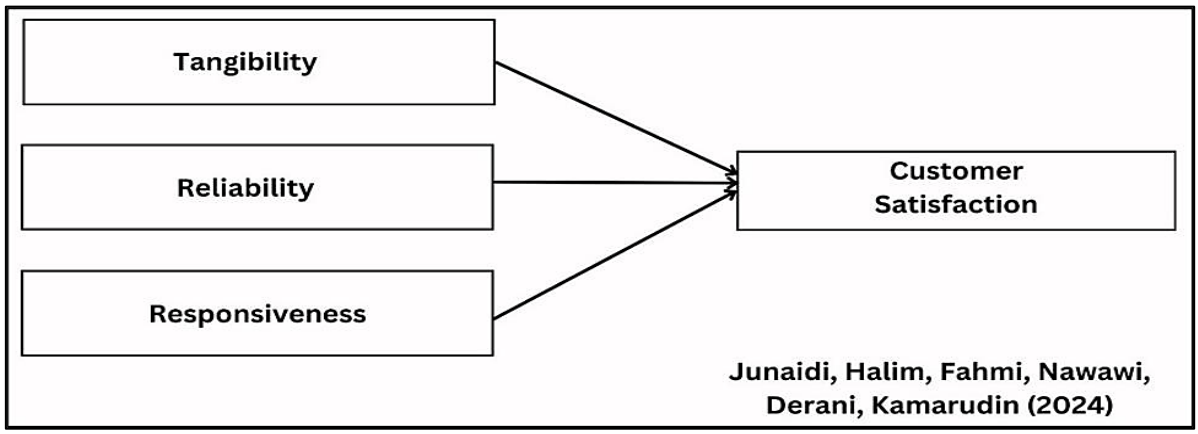

Figure 1: Conceptual Framework

2.0 METHODOLOGY

This study employed a quantitative research design to investigate the relationship between service quality dimensions tangibility, reliability, and responsiveness and customer satisfaction in Malaysia's budget hotel sector. The SERVQUAL model served as the study's conceptual foundation, with the three selected dimensions as independent variables and customer satisfaction as the dependent variable. Data were collected using a structured online questionnaire distributed via social media, email campaigns, and tourism websites. The instrument was divided into three sections: (1) demographic information, (2) service quality perception using a 5-point Likert scale, and (3) customer satisfaction, such as intention to revisit and recommend. A pilot test with 30 respondents confirmed the reliability of the tool, with Cronbach's alpha values exceeding 0.7. The target population consisted of tourists who had stayed in budget hotels in Malaysia within the past year, for at least two nights. A purposive sampling technique was used, and the sample size of 384 was determined using Krejcie and Morgan's (1970) table to ensure statistical validity. Additionally, hotel staff with over one year of experience were included to provide supplementary insights. Primary data were supported by secondary sources, including academic journals, government tourism reports, and online customer reviews (e.g., TripAdvisor, Google). The study also included direct observations of service delivery at selected budget hotels to validate customer-reported experiences. Data were analyzed using SPSS, applying descriptive statistics, correlation analysis, and multiple regression to examine the influence of service quality on customer satisfaction. Ethical considerations such as informed consent, anonymity, and voluntary participation were strictly observed. This methodology ensured a valid, reliable, and replicable approach to understanding service quality's impact on customer satisfaction in the Malaysian budget hotel context.

3.0 RESULTS AND DISCUSSION

This section presents the demographic profile of the 242 respondents who participated in the survey. The questionnaire covered the respondents' gender, race, age, education level, purpose of visit, and marital status. The findings reveal that 55% of the respondents were female, while 45% were male. In terms of race, the majority were Malay (55.4%), followed by Indian (18.2%), Chinese (16.5%), and others (9.9%). Most respondents were between the ages of 18–24 (32.6%) and 25–31 (24.4%), indicating a younger demographic that tends to prefer budget or low-cost hotel options. Regarding educational background, 39.7% of respondents held a bachelor's

degree, 29.8% had a diploma, 26% had a master's degree, and 4.5% held a PhD. The majority of respondents (61.6%) were staying at budget hotels for holidays, while 29.3% were on business trips, and 9.1% cited other purposes. As for marital status, most respondents were single (62.8%), with the remaining 37.2% being married. These findings suggest that young, educated, and predominantly single travelers are the primary customers of budget hotels in Malaysia.

Table 1: Demographic Profile

Demographic	Item	Frequency	Valid Percentage
Gender	Male	109	45%
	Female	133	55%
Race	Malay	134	55.4%
	Chinese	40	16.5%
	Indian	44	18.2%
	Others	24	9.9%
Age	18-24 years old	79	32.6%
	25-31 years old	59	24.4%
	32-38 years old	36	14.9%
	39-45 years old	38	15.7%
	46 and above	30	12.4%
Educational Level	Diploma	72	29.8%
	Bachelor's Degree	96	39.7%
	Master/s Degree	63	26%
	PhD	11	4.5%
Purpose of Visit	Business Trip	71	29.3%
	Holiday	149	61.6%
	Others	22	9.1%
Marital Status	Single	152	62.8%
	Married	90	37.2%

3.1 Tables and figures

3.1.1 Descriptive Analysis

Descriptive analysis is a technique which is used in describing the sample of a research. The data is computed into mean and standard deviation. Mean value obtained gives the average some of their response for each of the items that the respondents answered. While standard deviation is used to measure the dispersion of the data in which how close the entire set of data is to the average value. The lower value of standard deviation, the closer is the data to the average value.

3.1.2 Descriptive analysis: Responsiveness

This table presents mean scores and standard deviations for each item under the responsiveness construct. The item with the highest mean score (4.09) was "The staff at the hotel are always willing to help their customers", showing that willingness to help is a highly valued trait. Other

items, such as providing prompt services (mean = 3.92) and informing customers about service timings (mean = 3.97), also scored well. The lowest was still high at 3.88. The small standard deviations (0.877–1.038) indicate that responses were closely grouped around the mean, showing general agreement among respondents about staff responsiveness.

Table 2: Descriptive Analysis for IV 1 – Responsiveness

Process					
No.	**Items**	**Min**	**Max**	**Mean**	**Std. Deviation**
1.	The staff are always ready to respond to customers' requests.	1.00	5.00	3.88	0.877
2.	The staff at the hotel are always willing to help their customers.	1.00	5.00	4.09	0.958
3.	The staff always inform their customers when the services will be performed.	1.00	5.00	3.97	1.038
4.	The staff always provide prompt services to their customers.	1.00	5.00	3.92	0.934
Average Mean Score				**3.97**	

3.1.3 Descriptive analysis: Reliability

Table 3: Descriptive Analysis for IV 1 – Reliability

Process					
No.	**Items**	**Min**	**Max**	**Mean**	**Std. Deviation**
1.	The staff always perform services as promised.	1.00	5.00	3.92	0.950
2.	The staff can perform the service at the time promised.	1.00	5.00	3.89	0.897
3.	The staff are dependable in handling customer-service problems.	1.00	5.00	3.90	0.919
4.	The hotel ensures that customers' data and records are kept confidential.	1.00	5.00	4.11	0.945
Average Mean Score				**3.96**	

Reliability items also scored highly. The highest-rated item (mean = 4.11) was “The hotel ensures that customers’ data and records are kept confidential”, demonstrating how important data privacy is to customers. Other high scores (around 3.90) for items like staff dependability and timeliness in service delivery highlight that reliability plays a central role in shaping guest satisfaction. Standard deviations (0.897–0.950) reflect a moderate spread, suggesting consistent perceptions among respondents.

3.1.4 Descriptive analysis: Tangibility

Under tangibility, the highest-rated item was “The staff always show good appearance” (mean

= 4.07), suggesting that guests appreciate well-presented employees. The strategic location of hotels (mean = 4.00) and interior/exterior decor (mean = 3.91) were also rated highly. The lowest mean (3.82) was for furniture comfort, indicating a potential area for improvement. Standard deviations hovered around 0.883–1.045, showing consistent but slightly more varied responses.

Table 4: Descriptive Analysis for IV 1 – Tangibility

Process					
No.	**Items**	**Min**	**Max**	**Mean**	**Std. Deviation**
1.	The staff always show good appearance.	1.00	5.00	4.07	0.949
2.	The location of the hotel is strategic.	1.00	5.00	4.00	1.045
3.	The furniture provided is comfortable to use.	1.00	5.00	3.82	0.883
4.	The interior and exterior decorations are appealing.	1.00	5.00	3.91	0.895
Average Mean Score				**3.95**	

3.1.5 Descriptive analysis: Customer Satisfaction

Table 5: Descriptive Analysis for DV – Customer Satisfaction

Process					
No.	**Items**	**Min**	**Max**	**Mean**	**Std. Deviation**
1.	I am satisfied with the modern concept presented by the hotel.	1.00	5.00	3.90	0.949
2.	I am pleased with the courtesy of the staff towards me.	1.00	5.00	3.88	1.045
3.	I am pleased with the services provided by the hotel.	1.00	5.00	4.11	0.883
4.	Overall, I am very satisfied with the hotel's services and its performance.	1.00	5.00	3.97	0.895
Average Mean Score				**3.97**	

All satisfaction items were rated positively, with means ranging from 3.88 to 4.11. The highest score was for overall service provision (mean = 4.11), highlighting that guests were pleased with the quality of services received. The lowest (3.88) was still relatively high, indicating strong general satisfaction. The closeness of standard deviation values (0.883–1.045) again confirms consistency in how respondents evaluated their satisfaction levels.

3.1.6 Discussion

Based on the demographic data collected through Section A of the questionnaire, the majority of the respondents were female guests, comprising 55% of the total sample. In terms of age distribution, a significant proportion—approximately 73% of the guests were aged between 18 to 30 years. This indicates that younger travelers make up the largest customer base for budget

hotels in Malaysia. Ethnically, Malays formed the dominant group of respondents, making up about 96% of the total, while other ethnicities such as Indians and other minorities were underrepresented, each constituting only around 1%. Marital status analysis revealed that single guests were more likely to respond to the survey compared to married guests, highlighting a higher level of engagement among individual travelers. Most respondents indicated that their visit to the hotel was for leisure or relaxation purposes, with 39 respondents selecting this option, while only a small number, around seven guests, reported visiting the hotel for business purposes. This trend suggests that budget hotels in Malaysia primarily attract tourists and casual travelers rather than business clientele.

3.1.7 Recommendations

Following the completion of this research, several recommendations are proposed to improve customer satisfaction in Malaysian budget hotels. These suggestions are organized into three key areas: future academic research, hotel industry practices, and student engagement. This section provides a series of recommendations based on the findings of the study, with the aim of improving customer satisfaction in Malaysia's budget hotel sector. These suggestions are offered from the perspectives of future researchers, the hospitality industry, and students involved in hospitality education. The intention is to promote better practices, encourage deeper investigation, and support the development of customer-focused strategies within budget accommodations.

3.1.8 Future research

Future studies should consider expanding the respondent demographic to include a broader age range and different regions of Malaysia for more diverse insights. This will allow for better understanding of how age, culture, and locality influence satisfaction. Researchers are also encouraged to narrow the focus specifically on individual service quality dimensions such as empathy, assurance, or food services to allow for deeper analysis. Additionally, conducting comparative studies across multiple budget hotels would provide a more holistic view of the industry and help identify common strengths and weaknesses. Incorporating face-to-face interviews or on-site observations could also enrich the findings by adding qualitative depth.

3.1.9 Industry

For practitioners in the hotel industry, this research highlights the importance of strengthening internal service protocols. Hotel managers should focus on training staff to be more responsive and consistent in their service delivery. Investment in customer service training, even for budget accommodations, can significantly enhance guest experiences and improve retention. Moreover, feedback systems should be actively monitored so that management can respond swiftly to guest complaints or suggestions. Online reviews also play a critical role in shaping public perception, so hotels should prioritize addressing negative feedback constructively and professionally. Finally, hotels should ensure that facilities meet basic expectations for cleanliness, comfort, and accessibility, especially since these tangible factors strongly influence guest satisfaction in the budget hotel segment.

3.2.0 Student

From an academic standpoint, students conducting similar studies should consider gathering data over a longer time frame to ensure more accurate and representative results. Actively participating in hotel-based activities such as internships, training programs, or collaborative projects can provide a deeper understanding of how service delivery operates in real-world settings. This hands-on involvement will not only enhance the accuracy of data collection but

also help students develop practical skills that can benefit future research or professional endeavors in the hospitality field.

3.2.1 Limitations

As with any research project, this study faced several limitations that should be acknowledged. Firstly, the research was limited to a specific category of accommodations budget hotels in Malaysia—which may not represent the broader hotel industry or different classes of hospitality services. The study was also conducted during a restricted timeframe, which limited the number of responses collected. Although 242 responses were deemed valid, this may still be considered a small sample size for making generalizations about the entire Malaysian budget hotel market. Another limitation was the reliance on online survey tools due to time and logistical constraints. While digital forms were effective in reaching many respondents, some potential participants, particularly older individuals, may have been excluded due to unfamiliarity with online platforms. Furthermore, the use of structured questionnaires limited the scope for respondents to provide in-depth feedback or nuanced opinions. These constraints suggest that future research should aim for broader data collection methods, including in- person interviews or larger samples over extended periods.

4.0 CONCLUSION

In summary, this research has explored the key factors that influence customer satisfaction in Malaysia's budget hotel sector, with a focus on responsiveness, reliability, and tangibility. The findings reveal that guests place a high value on consistent service, helpful staff, and well-maintained facilities. While budget hotels are not expected to offer luxury, guests still expect professionalism, cleanliness, and prompt service. By addressing these core areas, budget hotels can improve guest satisfaction and build stronger customer loyalty. The study offers useful guidance not only to hotel operators but also to hospitality students and future researchers who aim to contribute to the growth and quality of Malaysia's tourism industry. Through continuous improvement in service quality, guest engagement, and facility standards, budget hotels can elevate their reputation and remain competitive in a rapidly evolving hospitality landscape.

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The Role of Street Food in Shaping Gastronomy Tourism Experiences in Pasir Gudang, Johor

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ABSTRACT

Street food plays a central role in shaping gastronomy tourism experiences by offering authentic, convenient, and accessible culinary encounters. In Pasir Gudang, Johor, street food is more than just a local delicacy, it acts as a cultural lens through which tourists can experience the region's diverse heritage. This study investigates the influence of street food on tourist satisfaction and destination appeal, focusing on three dimensions: authenticity, convenience, and accessibility. A quantitative research design was employed, utilizing structured questionnaires administered to 400 respondent with street food vendors across Pasir Gudang. The findings reveal that authenticity, reflected in cultural heritage, preparation methods, and local flavors is a key driver of tourist immersion. Convenience, including quick service and strategic vendor locations, significantly enhances the tourist experience, while accessibility in terms of affordability and inclusivity broadens street food's appeal. The originality of this research lies in its data-driven exploration of tourist perspectives and its implications for tourism planning. Practically, the study offers insights for local authorities, tourism stakeholders, and food entrepreneurs on integrating street food into broader tourism strategies, particularly under the "Visit Johor 2026" initiative. Ultimately, the study underscores street food's potential as both a cultural asset and economic contributor in sustainable tourism development.

Keywords: street food, gastronomy tourism, authenticity, convenience, accessibility, Pasir Gudang

1.0 INTRODUCTION

Street food plays a crucial role in shaping gastronomy tourism in Pasir Gudang by offering tourists an authentic taste of local culture through affordable and accessible food. Tourists often view street food not just as a meal but as a unique cultural experience. However, challenges such as limited promotion, inconsistent accessibility, and lack of proper infrastructure reduce its full tourism potential.

This study focuses on three key factors which is authenticity, convenience, and accessibility, which are believed to strongly influence tourist satisfaction and perception. The goal is to explore how these factors contribute to enhancing tourism experiences in Pasir Gudang, in support of tourism development plans like *Visit Johor 2026*.

2.0 LITERATURE REVIEW

Street food is increasingly acknowledged as a key element in gastronomy tourism due to its ability to reflect local identity, culture, and tradition. It allows tourists to explore a destination through its flavors and everyday culinary practices. Researchers have noted that food, especially street food, serves as both a cultural product and a tourist attraction, making it a valuable asset in tourism development.

One of the key aspects often discussed in the literature is authenticity. Tourists seek genuine experiences that represent the true culture of a place. Authentic street food offers a direct connection to local customs, recipes, and cooking methods. According to Şeyhanlıoglu and Becerikli (2023), the preservation of traditional food preparation is crucial in maintaining cultural heritage. However, some researchers warn that over-commercialization can lead to the loss of authenticity as vendors may adjust their food to suit tourist preferences.

Another important factor is convenience. Tourists are more likely to choose food that is quick, easy to find, and served in locations that are near attractions or accessible by foot. Khan and Rahman (2022) highlight that convenience is one of the main reasons tourists are drawn to street food. In urban destinations like Pasir Gudang, street food's ability to provide fast and affordable meals aligns well with tourist behavior, especially for those who are on tight schedules.

The literature also emphasizes accessibility as a determinant in street food's attractiveness to tourists. Accessibility refers to more than just location; it also includes pricing, dietary options, and openness to different customer backgrounds. Nguyen and Tran (2023) argue that for street food to be successful in tourism, it must be inclusive offering halal, vegetarian, and allergy-conscious options while keeping prices affordable for all.

Several studies also discuss the integration of digital tools in enhancing street food tourism. Tourists increasingly rely on online reviews, digital maps, and mobile payments when choosing food experiences. Researchers like Khoo and Chan (2023) point out that a lack of digital presence among vendors can limit their visibility and competitiveness in the tourism market.

In summary, past studies confirm that authenticity, convenience, and accessibility are central to the success of street food in shaping culinary tourism experiences. These three variables are interconnected and, when balanced effectively, contribute to tourist satisfaction and destination appeal. Therefore, understanding how these factors function in the context of Pasir Gudang is essential to improving its position as a gastronomic destination.

3.0 METHODOLOGY

This study adopted a quantitative research design to investigate how authenticity, convenience, and accessibility influence tourists' perceptions of street food in shaping gastronomy tourism experiences in Pasir Gudang, Johor. The research focused on collecting measurable data through a structured questionnaire to ensure consistency and replicability.

A total of 400 respondents were selected using a purposive sampling method, targeting tourists who had direct experience with local street food. This method ensured that the data gathered was relevant and reflective of actual tourist experiences in the area. Respondents came from various demographic backgrounds, mainly young adults and domestic travelers.

The primary instrument used was a questionnaire comprising two sections: demographic information and items related to the study's key variables. Each item was rated using a 5-point Likert scale, allowing for quantitative analysis of perceptions. To ensure reliability, the instrument was pilot-tested and validated using Cronbach's Alpha, where all constructs recorded values above 0.70.

Data were collected on-site at popular street food locations in Pasir Gudang, such as night markets and food courts. Ethical procedures, including informed consent and anonymity, were observed. The collected data were analyzed using SPSS, with both descriptive statistics and regression analysis applied to determine the strength of relationships between the variables.

The chosen methodology ensures that the findings of this study are both valid and reliable. It provides a strong foundation for understanding the contribution of street food to the tourism experience in Pasir Gudang, and the research process is designed to be replicable for future studies.

4.0 RESULTS AND DISCUSSION

4.1 Tables and Figures

4.1.1 Demographic

Table 1: Demographic Information (N = 400)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	208	52.0%
	Female	192	48.0%
Age	Under 18	13	3.3%
	18 - 24	210	52.5%
	25 - 34	116	29.0%
	35 - 44	29	7.2%
	45 - 54	19	4.8%
	55 and above	13	3.3%
Occupation	Student	256	64.0%
	employed	69	17.3%
	Self-employed	28	7.0%
	Unemployed	35	8.8%
	Retired	12	3.0%
Street food	Always	36	9.0%
	Often	138	34.5%
	Sometimes	165	41.3%
	Rarely	43	10.8%
	Never	18	4.5%

Based on the demographic analysis of the 400 respondents, the majority were male (52.0%), while female respondents accounted for 48.0%. Most of the participants were aged between 18

and 24 years old (52.5%), followed by those aged 25 to 34 (29.0%) and 35 to 44 (7.2%). A smaller portion of respondents were under 18 (3.3%), aged 45 to 54 (4.8%), and 55 and above (3.3%). In terms of occupation, a significant portion of the respondents were students (64.0%), followed by those who were employed (17.3%), unemployed (8.8%), self- employed (7.0%), and retired (3.0%). When asked about their frequency of consuming street food, most respondents reported that they consumed it sometimes (41.3%), followed by often (34.5%), rarely (10.8%), always (9.0%), and never (4.5%). These demographic characteristics suggest that the sample is largely composed of young individuals, mostly students, who frequently engage with street food culture making them a relevant group for exploring gastronomy tourism experiences in Pasir Gudang.

4.1.2 Reliability Test

Table 2: Result of Cronbach's Alpha

Variable	Items	Cronbach's Alpha Per Variable	Cronbach's Alpha
Authenticity	5	0.832	
Convenience	5	0.772	
Accessibility	5	0.860	**0.942**
The Role of Street Food	3	0.803	

A reliability analysis was conducted using Cronbach's Alpha to assess the internal consistency of the items under each construct. As shown in Table 4.2, the construct Authenticity recorded a Cronbach's Alpha value of 0.832 across 5 items, indicating good reliability. The Convenience construct achieved a Cronbach's Alpha of 0.772 for 5 items, which is also considered acceptable. Accessibility demonstrated excellent reliability with a Cronbach's Alpha of 0.860 across 5 items. Lastly, the construct Role of Street Food obtained a Cronbach's Alpha of 0.803 for 3 items, showing good internal consistency. According to Hilton et al. (2014), a Cronbach's Alpha value of 0.70 or above is generally considered acceptable in social science research. Therefore, all constructs used in this study demonstrate a strong level of reliability, confirming that the measurement instruments are consistent and appropriate for further analysis.

4.1.3 Normality Test

Table 3: Result of Normality Test

Variable	Items	df	Sig.
Authenticity	0.961		
Convenience	0.958		
Accessibility	0.921	400	**<0.001**
The Role of Street Food	0.907		

Liliefors Significance Correction

The Shapiro-Wilk test was conducted to assess whether the data follows a normal distribution. The test provides a statistic value and a corresponding p-value. A p-value less than 0.05 indicates that the data significantly deviates from a normal distribution.

As presented in Table 4.3, the Shapiro-Wilk test results for each variable which is Authenticity, Convenience, Accessibility, and Role of Street Food all reported p-values less than 0.001, suggesting that these data do not follow a normal distribution. The statistic values ranged from 0.907 to 0.961, with the degrees of freedom (df) for each test being 400.

This indicates that the distribution of the tested variables significantly deviates from normality ($p < 0.001$). As such, non-parametric methods, which do not assume normal distribution, should be considered for further analysis of these data sets.

4.2 Descriptive Analysis

4.2.1 Descriptive Analysis of Authenticity

Table 4: Result of Authenticity

Authenticity	Percentage of Respondents					Mean	Variable Mean
	SD	D	N	A	SA		
The street food I buy has a good taste	3.50%	8.50%	22.25%	34.00%	31.75%	3.8200	3.75
Street food represent to local food	5.00%	7.75%	23.23%	40.75%	23.25%	3.6950	
I prefer traditional street food over modernized versions	4.75%	8.75%	26.00%	36.25%	24.25%	3.6650	
I enjoy street food as part of a cultural experience	6.00%	8.75%	14.75%	40.25%	30.25%	3.800	
I would like to enjoy authentic local street food	4.75%	8.00%	19.25%	40.75%	27.25%	3.7775	

The data shows that tourists generally agree on the benefits of smart tourism technologies, with the highest mean score (3.82) for accessing useful tourism-related information. The lowest mean (3.67) still indicates a positive view, particularly regarding getting others' opinions on destinations.

Over 23% of respondents selected "Strongly Agree" across all informativeness items, indicating a consistent perception of these technologies as informative. Based on Moidunny's (2009) scale, the overall mean of 3.75 is considered high.

In summary, tourists view smart tourism technologies as valuable tools for gaining accurate, relevant travel information and making better decisions.

4.2.2 Descriptive Analysis of Convenience

The data shows that tourists view street food in Pasir Gudang positively, with the highest mean score (3.95) for enhancing overall experience, and the lowest (3.74) relating to ease of access. Despite minor concerns, responses indicate general agreement on the benefits of street food.

Table 5: Result of Convenience

Convenience	Percentage of Respondents					Mean	Variable Mean
	SD	D	N	A	SA		
Street food is quick and easy to buy.	4.25%	5.75%	20.75%	41.00%	28.25%	3.8325	3.84
Street food stalls are in good locations for tourist	3.00%	7.00%	19.75%	37.00%	33.25%	3.9050	
Street food is available at convenience hours	4.00%	11.00%	18.50%	36.00%	30.50%	3.7800	
Pasir Gudang popular for street food destination	3.75%	9.00%	28.75%	26.25%	32.25%	3.7425	
I prefer street food that is served in packaging that is easy to carry	2.75%	8.75%	18.75%	30.50%	39.25%	3.9475	

With an overall mean of 3.84, classified as high by Moidunny (2009), tourists find street food convenient and easy to engage with. The strong agreement levels suggest that street food is well-integrated into the local tourism experience.

4.2.3 Descriptive Analysis of Accessibility

Table 6: Result of Accessibility

Accessibility	Percentage of Respondents					Mean	Variable Mean
	SD	D	N	A	SA		
Street food stalls are easily found in strategic location	6.00%	8.50%	19.25%	34.75%	31.50%	3.7725	3.85
I can easily get information about street food	3.75%	12.75%	22.00%	25.75%	35.75%	3.7700	

I buy street food because it is convenient	4.25%	10.25%	19.50%	28.75%	37.25%	3.8450
Street food is affordable	4.00%	11.50%	16.75%	25.00%	42.75%	3.9100
I like that street food offer a variety of choices	4.25%	8.75%	17.00%	29.00%	41.00%	3.9375

The findings show that tourists perceive street food in Pasir Gudang as a valuable source of local culinary knowledge, with a high mean score of 3.82. The lowest mean (3.67) reflects slightly less emphasis on accessing opinions via digital platforms.

The overall mean of 3.75, within the high range (Moidunny, 2009), indicates strong agreement that street food offers not just food, but also cultural and educational value.

4.2.4 Descriptive Analysis of The Role of Street Food

Table 7: Result of The Role of Street Food

The Role of Street Food	Percentage of Respondents					Mean	Variable Mean
	SD	D	N	A	SA		
Street food plays a significant role in the development of gastronomic tourism in Pasir Gudang.	3.25 %	8.50%	18.50%	33.50%	36.25%	3.9100	3.95
Street food is a major factor in attracting tourists to explore local culture and cuisine	3.50 %	10.00%	17.75%	33.25%	35.50%	3.8725	
Street food festivals and events are an effective way to promote Pasir Gudang as a gastronomic destination	4.25 %	6.50%	21.75%	23.50%	44.00%	3.9650	

The results show strong agreement that street food plays a key role in promoting Pasir Gudang, with the highest mean (3.97) for street food festivals and the lowest (3.87) for its role in attracting tourists to local culture.

With an overall mean of 3.95 (high range per Moidunny, 2009), tourists clearly view street food as both a culinary attraction and an effective tool for promoting gastronomic tourism and cultural engagement.

5.0 CONCLUSION

This study explored the role of street food in shaping gastronomy tourism experiences in Pasir Gudang, Johor, focusing on three key variables: authenticity, convenience, and accessibility. The findings reveal that all three variables significantly influence tourist perceptions, with accessibility being the most dominant factor. Tourists are drawn to street food that is affordable, available in strategic locations, and easy to purchase, while still maintaining cultural authenticity.

These results provide valuable insights for tourism planners and local authorities. Street food should be promoted not just as a local necessity but as a tourism asset that reflects the identity of Pasir Gudang. Improvements in vendor facilities, hygiene, digital marketing, and tourist-friendly infrastructure can further elevate its role in tourism.
For future research, a broader sample covering other districts in Johor or even international tourists could provide more generalizable insights. A mixed-method approach that includes interviews or observations may also deepen the understanding of cultural and emotional responses to street food.

In conclusion, street food in Pasir Gudang has great potential to serve as a driver for culinary tourism. With strategic support and integration into tourism policy, it can become a key highlight in Johor's efforts to position itself as a leading gastronomy destination in Malaysia and Southeast Asia.

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Understanding Heritage Cuisines and Tourism: A Case Study of Nasi Briani Gam, Johor

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ABSTRACT

Nasi Briani Gam is a traditional Johorean dish renowned for its distinctive flavor, unique preparation methods, and rich cultural symbolism. Firmly embedded in Johor's culinary heritage, this dish serves as an important marker of local identity. With the expansion of food tourism, effectively promoting *Nasi Briani Gam* as a cultural product necessitates a comprehensive understanding of tourist perceptions. This study investigates how three principal elements, ingredients, taste, and presentation, influence tourists' perceptions of authenticity, satisfaction, and cultural significance .A quantitative research approach was adopted, collecting data from 400 tourists visiting Johor through structured questionnaires assessing their experiences and evaluations of the dish. Results demonstrate that tourists place considerable importance on the use of traditional ingredients, the harmonious blend of spices, and the visual presentation of *Nasi Briani Gam*, all of which contribute to its recognition as a heritage cuisine. The study's originality stems from its focused examination of a single culturally significant dish, providing empirical insights into the nexus of food and cultural tourism. Practically, the findings offer valuable recommendations for tourism stakeholders, marketers, and culinary entrepreneurs aiming to promote Johor's gastronomic identity and reinforce *Nasi Briani Gam*'s status within Malaysia's rich culinary heritage.

Keywords: nasi briani gam, heritage cuisine, authenticity, taste, presentation

1.0 INTRODUCTION

Gastronomy plays a vital role in cultural tourism, acting as both a reflection of a destination's heritage and a medium for intercultural exchange (UNWTO, 2021). In Johor, Nasi Biryani Johor notably the local Biryani Gam variant has become a cultural symbol, blending Persian and Indian culinary influences with local traditions such as the use of pandan leaves and telur pindang, prepared through a traditional dum cooking method (Mohd Farhaan Shah, 2023). As food tourism gains global prominence, heritage dishes like Nasi Biryani Johor offer strong potential for promoting local identity and enriching tourist experiences (Ullah et al., 2022). However, there remains limited understanding of how tourists perceive key elements of this dish its ingredients, taste, and presentation in relation to authenticity and cultural significance (Ellis et al., 2018; Som et al., 2020). Without such insights, positioning Nasi Biryani Johor as a globally recognised culinary heritage product may prove challenging, particularly as the state pursues UNESCO recognition.

This study aims to explore tourists' perceptions of Nasi Biryani Johor, focusing on how its ingredients, flavours, and presentation contribute to perceptions of authenticity and overall satisfaction (Su et al., 2020). Academically, this research enriches the literature on gastronomic tourism by examining the interplay between food heritage and tourist experience. Practically, it provides valuable guidance for stakeholders seeking to market Nasi Biryani Johor as a cultural attraction and strengthen destination branding. Furthermore, by promoting traditional culinary

practices amid globalization, this study supports both cultural preservation and sustainable tourism development in Johor (Ullah et al., 2022).

2.0 METHODOLOGY

This study employed a quantitative research methodology to investigate tourists' perceptions of Nasi Biryani Gam as a heritage food in Johor. The methodology outlines the research design, data collection methods, research instruments, and sampling design, all of which were chosen to ensure the reliability and validity of the findings.

A structured questionnaire served as the primary research instrument, designed to collect data on respondents' demographic profiles and their perceptions of key components of Nasi Biryani Gam namely ingredients, taste, and presentation. The questionnaire included a combination of Likert-scale and multiple-choice items to ensure comprehensive and measurable responses. To enhance the instrument's reliability and clarity, a pilot test was conducted with a selected group of tourists and gastronomy enthusiasts to refine the wording and structure of the questions.

Primary data were collected from over 400 respondents across various tourist sites in Johor, comprising both domestic and international visitors. The sample size exceeded the recommended 400 respondents based on Krejcie and Morgan's (1970) sample size table, thereby strengthening the validity of the study. A random sampling technique was applied to ensure that every eligible tourist had an equal opportunity to be included, thus reducing selection bias and increasing the generalizability of the results.

In addition to primary data, secondary data were gathered from academic journals, scholarly articles, and previous studies relevant to Nasi Biryani Gam, heritage food, and gastronomic tourism. These sources provided essential context and supported the formulation of the research objectives and questions.

This methodological framework ensures a rigorous and systematic approach in examining tourists' perceptions toward the recognition and promotion of Nasi Biryani Gam as a cultural and culinary heritage of Johor.

3.0 RESULTS AND DISCUSSION

This chapter presents the results of the study on how tourists perceive Nasi Biryani Johor as a heritage food. The analysis covers response rate, survey reliability, normality testing, descriptive statistics, and regression analysis to help answer the research questions and test the study's hypotheses. A total of 400 valid responses were collected, achieving a 100% response rate with no missing data. The survey demonstrated strong reliability, with all measurement scales showing high internal consistency (Cronbach's alpha > 0.70). Although the data were not normally distributed, the large sample size allowed for reliable use of regression analysis. Descriptive statistics provided an overview of tourists' perceptions, while multiple regression analysis examined how ingredients, taste, and presentation influenced both the perceived heritage value of the dish and overall tourist satisfaction. The results reveal which factors most strongly shape tourists' experiences and reinforce Nasi Biryani Johor's status as a cherished heritage cuisine.

The findings show that all three variables have a strong and significant positive effect on tourists' perceptions of the dish's cultural and heritage value. Among these, Presentation demonstrated the strongest influence (Std Beta = 0.774, t = 22.190, p < .001), indicating that the way Nasi Biryani Gam Johor is presented plays a key role in shaping tourists' understanding and appreciation of it as part of Johor's cultural identity. Taste also showed a very strong positive effect (Std Beta = 0.756, t = 23.023, p < .001), suggesting that the enjoyment of the dish's unique flavour significantly enhances how tourists view its cultural importance. Likewise, Ingredients had a strong positive impact (Std Beta = 0.724, t = 20.937, p < .001), highlighting that the quality, authenticity, and freshness of the ingredients contribute meaningfully to tourists' perceptions. Since all variables recorded statistically significant results (p < .001) and high t-values, the hypotheses for all three variables are supported. These insights reinforce the importance of focusing not only on taste and authenticity, but also on visual presentation when promoting Nasi Biryani Gam Johor as part of Johor's cultural tourism offerings.

Table 1: Regression Analysis Between Independent Variable and Dependent Variable

Hypothesis	Std Beta	Std Error	T-Value	Desicion
Ingredient	0.724	0.038	20.937	Supported
Taste	0.756	0.033	23.023	Supported
Presentation	0.774	0.035	22.190	Supported
Dependent Variable: Understanding heritage cuisines and tourism: A case study of Nasi Briyani Gam, Johor.				

4.0 CONCLUSION

This study has explored the cultural and tourism significance of Nasi Biryani Gam Johor, focusing on its key elements Ingredients, Taste, and Presentation as essential components in preserving and promoting Johor's culinary heritage. Originating from a blend of Middle Eastern, Indian, and Malay culinary influences, Nasi Biryani Gam Johor has evolved into a distinctive heritage dish that reflects the region's rich cultural identity. Today, it has become a signature part of Johor's gastronomic landscape, enjoyed not only during special occasions but also as an everyday favorite and a highlight of cultural tourism experiences. Its presence in local eateries, festivals, and tourism campaigns reinforces regional identity and contributes to Johor's appeal as a culinary destination.

The study's findings highlight the significance of Ingredients, Taste, and Presentation in shaping tourists' perceptions of Nasi Biryani Gam Johor as a heritage food. Each element contributes meaningfully to tourists' understanding of the dish's cultural value and enhances their overall experience. The reliability analysis demonstrated excellent internal consistency (Cronbach's Alpha > 0.70) across all measurement scales, confirming the robustness of the research instrument. Multiple regression analysis further revealed that all three factors Ingredients, Taste, and Presentation positively influenced tourists' understanding of heritage cuisine and overall satisfaction. Notably, Presentation emerged as the strongest predictor of

perceived cultural significance, underscoring the importance of visual appeal in modern tourism, especially in the era of social media-driven travel experiences.

For future research, it is recommended to conduct comparative studies across different heritage dishes and regions to explore how traditional foods contribute to cultural tourism in broader contexts. Including a more diverse sample, particularly international tourists, would provide deeper insights into how global visitors perceive Nasi Biryani Gam Johor. Additionally, employing qualitative approaches such as interviews and focus groups could enrich the understanding of tourists' personal and emotional connections with the dish. Exploring how Nasi Biryani Gam Johor is marketed through digital platforms and its role within culinary tourism packages would also inform practical strategies for tourism promotion. Finally, examining the impacts of modernization and globalization on food heritage could offer valuable perspectives on preserving the authenticity of Nasi Biryani Gam Johor as an enduring symbol of Johor's cultural identity.

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6 REKA BENTUK KOMUNIKASI VISUAL & MEDIA BAHARU

Aplikasi Kandungan *Edutainment* Sebagai Alat Bantu Mengajar (ABM) Dalam Meningkatkan Penguasaan Membaca Tahun 1

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ABSTRAK

Penguasaan kemahiran asas dalam kalangan murid Tahun 1 masih menjadi cabaran di Malaysia, khususnya bagi murid yang menghadapi kesukaran dalam literasi Bahasa Melayu iaitu membaca. Kajian ini bertujuan membangunkan aplikasi kandungan berbentuk *edutainment* sebagai Alat Bantu Mengajar (ABM) untuk meningkatkan penguasaan membaca dalam kalangan murid Tahun 1. Kajian ini melibatkan dua orang guru iaitu guru Bahasa Melayu dan guru Pemulihan sebagai peserta kajian utama, pendekatan kualitatif digunakan melalui kaedah pemerhatian dan temubual. Aplikasi *edutainment* yang dibangunkan mengintegrasikan elemen interaktif seperti kuiz, visual menarik, serta audio naratif untuk meningkatkan motivasi dan penglibatan murid dalam pembelajaran literasi. Dapatan kajian menunjukkan bahawa penggunaan aplikasi *edutainment* dapat meningkatkan minat belajar, memudahkan pemahaman konsep asas membaca, dan membina sikap positif terhadap pembelajaran Bahasa Melayu. Kesimpulannya, integrasi aplikasi *edutainment* sebagai ABM berpotensi menjadi pendekatan inovatif yang berkesan dalam memperkukuh literasi awal murid, sejajar dengan keperluan pendidikan abad ke-21. Kajian ini juga mencadangkan penggunaan teknologi secara lebih meluas dalam pendidikan awal serta penyelidikan lanjut bagi mempertingkatkan keberkesanan kaedah pembelajaran interaktif.

Kata Kunci: aplikasi edutainment, alat bantu mengajar, pembelajaran interaktif, teknologi pendidikan

1.0 PENGENALAN

Kemahiran membaca merupakan tunjang utama dalam pembangunan literasi awal kanak-kanak, khususnya dalam kalangan murid Tahun 1 yang baru memulakan alam persekolahan. Penguasaan membaca bukan sahaja penting untuk kejayaan akademik, malah merupakan asas untuk memahami pelbagai subjek lain. Namun, realitinya masih terdapat murid di peringkat awal persekolahan yang mengalami kesukaran dalam menguasai kemahiran asas membaca terutama dalam Bahasa Melayu. Hal ini menjadi cabaran utama kepada guru-guru terutama yang mengajar murid dalam kategori LINUS (Literasi dan Numerasi)

Dalam era digital masa kini, penggunaan teknologi dalam Pendidikan semakin diberi penekanan. Pendekatan berasaskan *edutainment* atau gabungan Pendidikan dan hiburan dilihat berpotensi untuk meningkatkan keberkesanan pembelajaran murid. Elemen interaktif seperti visual menarik, kuiz dan naratif audio mampu menarik minat serta meningkatkan motivasi murid untuk belajar. Justeru, penggunaan aplikasi kandungan *edutainment* sebagai Alat Bantu Mengajar (ABM) dilihat sebagai satu inovasi pedagogi yang berupaya menyokong penguasaan literasi dalam kalangan murid Tahun 1.

1.1 Latar Belakang Kajian

Kajian ini dijalankan di Sekolah Kebangsaan Kota Masai 3 yang terletak di Pasir Gudang, Johor. Sekolah ini mempunyai murid-murid daripada pelbagai latar belakang, termasuk mereka yang menghadapi kesukaran dalam penguasaan kemahiran membaca dalam subjek Bahasa Melayu. Berdasarkan data yang diperoleh daripada pihak sekolah, seramai 34 orang murid

sedang mengikuti kelas pemulihan disebabkan kelewatan dalam menguasai literasi asas. Namun begitu, meskipun pelbagai usaha telah dijalankan, masih terdapat kelemahan dalam pencapaian literasi asas dalam kalangan murid Tahun 1.

1.2 Pernyataan Masalah

Walaupun pelbagai inisiatif telah dilaksanakan bagi meningkatkan penguasaan literasi dalam kalangan murid Tahun 1, namun masih terdapat segelintir murid yang belum menguasai kemahiran asas membaca, khususnya dalam Bahasa Melayu (KPM, 2024). Kaedah pengajaran konvensional yang berpusatkan guru dan kurang unsur interaktif sering kali gagal menarik perhatian serta mengekalkan fokus murid semasa proses pembelajaran (Hashim & Yunus, 2019). Akibatnya, murid menjadi pasif, kurang bermotivasi, dan mudah hilang minat untuk belajar.

Tambahan pula, kekurangan bahan bantu mengajar yang sesuai dengan tahap kognitif dan minat murid turut menyumbang kepada masalah ini (Rahim et al., 2021). Guru juga berhadapan kesukaran untuk menyesuaikan kaedah pengajaran yang mampu memenuhi keperluan pelbagai tahap murid. Oleh itu, wujud keperluan mendesak untuk membangunkan satu bentuk bahan bantu mengajar yang inovatif dan mesra murid.

2.0 METODOLOGI

Pendekatan kualitatif telah digunakan untuk menilai bagaimana aplikasi edutainment dapat meningkatkan penguasaan pembelajaran murid, khususnya dalam kemahiran asas seperti membaca. Kaedah utama pengumpulan data ialah melalui pemerhatian secara langsung dan temubual tidak berstruktur yang dijalankan bersama guru. Pendekatan ini membolehkan ia memahami dengan lebih mendalam bagaimana aplikasi digunakan dalam bilik darjah, tahap keterlibatan murid, serta pandangan guru terhadap keberkesanan aplikasi tersebut sebagai alat bantu mengajar.

Pemerhatian dijalankan dalam suasana pembelajaran sebenar untuk mencatat tingkah laku murid ketika menggunakkan aplikasi, termasuk tahap focus, interaksi, motivasi, serta respons terhadap aktiviti yang disediakan dalam aplikasi tersebut. Pemerhatian ini juga memberi gambaran awal tentang kesesuaian reka bentuk antaramuka dan keupayaan aplikasi menarik minat murid.

Untuk mengumpul data, langkah- langkah berikut telah dijalankan:

2.1 Pemerhatian

Sesi pemerhatian telah dijalankan semasa proses pengajaran dan pembelajaran yang melibatkan penggunaan aplikasi *edutainment*. Pemerhatian ini dilakukan secara langsung di dalam bilik darjah bagi menilai tahap keterlibatan murid, cara mereka berinteraksi dengan aplikasi, serta mengenal pasti tingkah laku yang ditunjukkan semasa aktiviti pembelajaran berlangsung. Aspek-aspek yang diberi perhatian termasuklah tahap tumpuan murid, respons terhadap arahan guru, cara murid mengendalikan aplikasi serta keberkesanan aplikasi dalam menarik minat mereka. Dapatan daripada pemerhatian ini membantu penyelidik mendapatkan gambaran menyeluruh tentang sejauh mana aplikasi dapat mempengaruhi keterlibatan murid secara aktif dalam proses pembelajaran.

2.2 Temubual Tidak Berstruktur

Temubual tidak berstruktur telah dijalankan bersama dua orang guru yang terlibat secara langsung dalam pelaksanaan penggunaan aplikasi dalam pengajaran. Temubual ini bertujuan untuk memahami pengalaman sebenar guru sebagai pengguna, termasuk persepsi mereka terhadap keberkesanan aplikasi dari sudut pedagogi dan kesesuaian kandungan dengan tahap murid pemulihan. Di samping itu, temubual ini juga membolehkan guru memberikan maklum balas secara terbuka tentang kelebihan, kekangan, serta cadangan penambahbaikan terhadap penggunaan aplikasi tersebut. Pendekatan temubual tidak berstruktur membolehkan penyelidik memperoleh data yang lebih mendalam, kerana ia memberi ruang kepada guru untuk berkongsi pandangan dan pengalaman tanpa terikat dengan soalan-soalan yang ketat atau terlalu formal.

2.3 Sampel Dan Populasi Kajian

Sampel kajian ini terdiri daripada dua orang guru iaitu guru pemulihan dan guru bahasa melayu dari Sekolah Kebangsaan Kota Masai 3 yang terlibat secara langsung dalam memberikan pandangan mengenai penggunaan aplikasi *edutainment* dalam proses pengajaran. Selain itu, seramai 34 orang murid pemulihan dari sekolah yang sama dan dari kelas 1 Topaz turut terlibat dalam kajian ini bagi tujuan penilaian keberkesanan penggunaan aplikasi *edutainment* dalam pembelajaran mereka.

3.0 PERBINCANGAN

Bahagian ini membentangkan hasil kajian yang diperoleh melalui kaedah pemerhatian dan temu bual. Pemerhatian ke atas murid Tahun 1 semasa penggunaan aplikasi edutainment iaitu menilai penglibatan, kefahaman, pencapaian serta tindak balas terhadap antara muka pengguna (UI) dan pengalaman pengguna (UX). Temu bual bersama guru pula mengumpul maklum balas tentang motivasi murid, kesesuaian kandungan dan kemudahan penggunaan. Data dianalisis secara kualitatif untuk mengenal pasti kesan aplikasi terhadap pembelajaran murid.

3.1 Pemerhatian Murid Menggunakkan Aplikasi *Edutainment*

Jadual 1: Pemerhatian murid.

Aspek UI/UX	Pemerhatian/Dapatan	Penjelasan
Reka bentuk antaramuka (UI)	Warna ceria dan ikon besar menarik perhatian murid	Sesuai untuk peringkat umur
Navigasi Aplikasi	Murid dapat menekan dengan mudah tanpa bantuan	Reka bentuk butang yang jelas dan mesra pengguna
Interaktiviti (UX)	Murid memberi respon dengan mudah tanpa bantuan	Menunjukkan aplikasi menarik dan menyeronokkan
Arahan dalam aplikasi	Murid memahami arahan berbentuk visual	Kandungan disampaikan dengan efektif tanpa perlu banyak bimbingan

Tindak balas murid (UX)	Murid senyum, ketawa, dan berbincang dengan rakan	Tanda mereka seronok dan terlibat secara aktif
Kefahaman kandungan	Murid berjaya menyelesaikan dengan betul	Aplikasi menyokong pembelajaran yang berkesan

Rajah 1: Penglibatan murid menggunakkan Aplikasi *Edutainment*

Berdasarkan rajah 1, pemerhatian yang dijalankan mendapati murid menunjukkan minat dan keterujaan semasa menggunakan aplikasi *edutainment*. Mereka kelihatan bersemangat untuk mencuba aktiviti dalam aplikasi, seperti padankan huruf ke tempat kosong atau mengenal huruf menggunakkan gambar. Dalam satu sesi pemerhatian, murid berkumpul di hadapan komputer riba dan secara bergilir-gilir mencuba tugasan dalam aplikasi sambil memberikan sokongan sesama rakan.

Rajah 2: Maklum balas guru-guru

Berdasarkan rajah 2, guru yang terlibat menyatakan bahawa penggunaan aplikasi edutainment mampu menarik minat murid, terutamanya mereka yang sebelum ini kurang memberi tumpuan dalam pembelajaran secara tradisional. Peningkatan minat ini dapat dilihat apabila murid lebih aktif dan terlibat dalam aktiviti pembelajaran menggunakan aplikasi tersebut berbanding

kaedah konvensional yang kurang interaktif. Sehubungan itu, guru turut menyatakan bahawa media interaktif yang juga berfungsi sebagai alat bantu mengajar ini memberi impak positif kepada guru dalam mewujudkan suasana pengajaran dan pembelajaran yang lebih harmoni dan berkesan. Menurut Abd Samad, tindakan Kementerian Pendidikan Malaysia (KPM) yang menjadikan Teknologi Maklumat dan Komunikasi (ICT) sebagai salah satu alat bantu mengajar adalah langkah yang tepat dalam usaha meningkatkan kualiti pengajaran dan pembelajaran di sekolah.

4.0 KESIMPULAN

Kajian ini menunjukkan bahawa aplikasi kandungan *edutainment* mempunyai impak positif dalam meningkatkan penguasaan membaca murid Tahun 1, khususnya dalam aspek motivasi, penglibatan, dan pemahaman konsep asas. Integrasi elemen interaktif dan audio naratif membantu murid belajar dengan lebih menyeronokkan dan berkesan. Walaupun terdapat beberapa cabaran seperti keperluan latihan guru dan kemudahan teknologi, aplikasi ini tetap menjadi pendekatan inovatif yang sesuai dengan kehendak pembelajaran abad ke-21. Oleh itu, disyorkan agar aplikasi *edutainment* ini diimplementasikan secara lebih meluas dalam PdP literasi awal, serta kajian lanjut dilakukan untuk menambahbaik ciri dan keberkesanannya. Penggunaan teknologi sebagai alat bantu mengajar bukan sahaja meningkatkan penguasaan kemahiran membaca tetapi juga membentuk sikap positif terhadap pembelajaran dalam kalangan murid.

PENGHARGAAN

Segala puji dan syukur ke hadrat Allah SWT kerana dengan limpah kurnia-Nya, saya berjaya menyiapkan kajian ini dengan jayanya. Saya ingin merakamkan setinggi-tinggi penghargaan dan terima kasih kepada penyelia saya, Puan Mazlisa Mohd Isa, atas tunjuk ajar, bimbingan, dan sokongan yang tidak pernah jemu sepanjang proses kajian ini dijalankan.

Ucapan terima kasih juga ditujukan kepada pihak sekolah, khususnya kepada guru-guru dan murid Tahun 1 yang terlibat, kerana telah memberikan kerjasama yang sangat baik sepanjang sesi pemerhatian dan temu bual dijalankan. Tidak lupa juga kepada rakan-rakan, serta ahli keluarga yang sentiasa memberi dorongan, semangat, dan sokongan moral dalam menyiapkan kajian ini. Akhir kata, saya amat menghargai setiap sumbangan, tidak kira besar atau kecil, yang telah membantu menjayakan kajian ini. Semoga segala usaha ini memberi manfaat kepada semua pihak yang terlibat dalam bidang pendidikan.

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Assessing Visitor Perceptions and Educational Impact of Travelogue Videos at Zoo Johor

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ABSTRACT

The utilization of the travelog videos inside the application to enhance the educational experience at Zoo Johor, the oldest wildlife conservation institution in Malaysia is examined in this research. Even though it has its historical value, the zoo faces the obstacles of providing educational content effectively, especially with younger audiences, for it is dependent on the conventional static displays and restricted use of multimedia resources. This study tries to identify the key factors impacting visitor experience on educational content in Zoo Johor, develop travelog video with interesting educational matter about zoo's animals and conservation and measure the user acceptance of the video produced. The research uses quantitative method, and information is gathered from visitors' views through surveys using Google Forms, in which visitors respond to the questions related to satisfaction and learning outcomes after watching the travelog video. It consisted of close ended questions that are described and analyzed using descriptive and inferential statistical tools to understand how visitors perceive of the effectiveness in terms of educational aspect. Significant statistical improvements in knowledge retention and in satisfaction with the travelog's educational content were demonstrated by those visitors who experienced the travelog video as opposed to traditional exhibits. A clear and a positive response to the features of the multimedia format used and the clarity is also gained from the data. In addition, the distribution of travelog video on digital platforms extended Zoo Johor's educational messaging to the wider audience. The videos also have positive educational effects on the zoo's educational goals, because by viewing them, visitors claim to be more satisfied and have a deeper association with conservation, compared to when they do not. Finally, it is shown in this research that the travelog videos functioned as an excellent means of enhancing Zoo Johor's educational experience, and relevant learnings may be applied by zoos worldwide to integrate usage of multimedia in attracting visitors.

Keywords: multimedia tools, travelogue videos, wildlife conservation education, zoo Johor

1.0 INTRODUCTION

According to Smith and Lee (2019), zoos have always been more than viewing enclosures for animals, they play important roles in conservation, education, as well as raising public awareness regarding the natural world. Zoo Johor, like other zoos in Malaysia, have a very special role to help the people understand the biodiversity as well as to handle local wildlife problems. Zoo Johor is actually one of the oldest zoo in the country as it was established in 1928. Nonetheless, although the zoo is of historical significance, the zoo still uses the same traditional ways of doing things such as using static signs boards or simple displays that may not fit such expectations that are expected by today's tech savvy audiences especially children who are used to interactive experiences and presentations which were highlighted by Ahmad and Noor (2021). As digital media rapidly becomes a powerful tool for education, interest is rising in the use of non-traditional forms to improve the learning engagement. For instance, travelogue video, as described by Chen et al. (2020), is one of the formats – a short documentary, a story driven video that combines factual content with visual and storytelling. The purpose of this study is to find a way that this information can be made readily accessible,

as well as more enriching experience to Zoo Johor visitors through a custom-made travelogue video. The methods outlined by Lim and Tan (2022) are used to measure the audience's satisfaction, understanding, emotional connection with the subject, and the conservation messages, through a survey given to the audience after they watch the video. The purpose is to look into the possibilities for traditional institutions, including zoos, in which digital transformation can take place, and where education is not only educational, but also inspiring and memorable.

1.1 Zoo Johor in General

According to Patrick et al., (2007), nowadays Zoos are much than family fun festivals; they have become an important institution to protect wildlife, conduct research about it and educate the public about the natural environment. Zoos are important in Malaysia because it bridges the gap between the rich biodiversity of the country and the wider public. According to Rosly and Halim (2018) these institutions provide people of all ages to learn on native and exotic species, understand balance of ecological and realize the responsibility to save a conservation. Of these institutions, Zoo Johor is special. It has almost been a century since it became one of the mainstay of the community in Johor Bahru. It is founded in 1928 by Sultan Ibrahim Ibni Almarhum Sultan Abu Bakar and is now the oldest zoo in Malaysia and one of the oldest in Southeast Asia (Tourism Johor, 2020). Started initially as a little animal sanctuary, Zoo Johor has since grown into a well-loved place visited by thousands of people each year from families, school groups and the visiting tourists. However, thanks to its historical importance, cheap admission fees and facile location within the urban centre, it is a destination suitable to a very wide demographic. In most cases, Zoo Johor is not merely a zoo for most Malaysians. This is a place of childhood nostalgia that provides generations of animal lovers and wildlife educators.

1.2 Zoo Johor

Importantly, zoo Johor is still essential in wildlife education and recreation, which provides more than 100 species of animals consisting of mammals, birds and reptile. It also provides visitors the opportunity to get up close with iconic species, such as graceful Bengal tiger, powerful Malayan crocodile, mischievous macaques and, brightly coloured peacocks. According to the Department of Wildlife and National Parks (2021) many of these species are native to Southeast Asia and are therefore Malaysians and anyone visiting to do with regional biodiversity in an easily accessible environment. Of course, the zoo is not as big and high technology as other modern zoological parks, but it has its own charm and people, families and school groups will come back there again and again. The affordable ticket prices and the welcoming atmosphere as well as location right in the heart of the city makes the zoo best suitable place to both casual visitors and educational trips. The infrastructure of Zoo Johor has been improved drastically in the rehabilitating of animal enclosures, better cleanliness as well as the struggle for the wellbeing of the animals shown in the Johor Zoo Annual Report (2022). Once again the zoo is also making the most of evolutionary progress.

But as for educational material, the zoo keeps on using traditional ways like printed signboards or static display. Even though these are comparatively functional, they don't manage to grab the attention of younger audience, which includes both children and teens, who are more used to engaging digital interactivity, video content and a more immersive learning tools; as delineated by Yahaya et al. (2020). The days of the zoo educating visitor after visitor are dwindling away and it is becoming clearer by the day that the zoo's educational approach is in need of updating. Today's visitor demands not only information, but wants captivating

images and stirring, engaging emotion. With an aim to catch up with today's audience and carry out its mission as a hub for conservation education, Zoo Johor can take advantage of multimedia elements like videos, apps and augmented reality to become part of its education offering.

1.3 Zoo Johor faces challenges in delivering effective educational content

Although the Zoo Johor is home to a wealth rich history and cultural value, the Zoo is still battling to offer visitors with educational content that is meaningful and engaging. The first issue is that the information provided on the animals is still very basis in terms of the traditional static signboards still in use. These signs are meant for a function but do not generate any interest of the new audience especially children and teenagers who are accustomed in immersive and visually stimulating lessons as elucidated by Falk et al. (2008). Reading facts off a board never has the same effects of more dynamic methods of storytelling. Another problem is the zoo's lack of the use of multimedia tools that would be able to improve the educational experience. Particularly, it lacks video travelogues (that is, short documentaries which blend real story telling with real footage) so the zoo is failing to develop a connection to its visitors in an engaging way. Showing the behavior of animals, the work of conservation, behind the scenes, and so on, these videos could be exciting to learn wildlife education than just a lecture, which could give a journey like experience. Also, such videos could be easily spread out online and the zoo's educational outreach could be extended to a greater audience than its immediate physical location. In addition, the non-availability of multilingual materials represents a barrier to non-Malay speaking visitors in terms of inclusivity as pointed out in Lim and Ong (2019). Zoos in an era of digital storytelling, when learning and connecting to the world is changing partially due to the storytelling, have got to keep up with the times. The story goes that if they (institutions such as Zoo Johor) fail to evolve, they will eventually be left behind as the leaders in education. Chen et al. (2020) also argue for the zoo to use video travelogues as a core tool for inspiring conservation awareness of visitors of all ages, and by adopting videos the zoo could supply a more engaging, accessible, and emotionally resonant means of storytelling.

2.0 METHODOLOGY

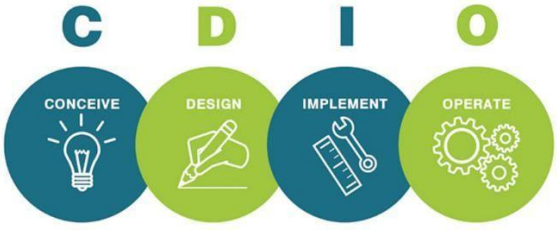


Figure 1: CDIO framework

The travelogue film which is developed in this study is used in the CDIO framework in order to improve the educational experiences at Zoo Johor. The Conceive phase derived from the necessity of interactive educational tools, since visitors of our new millennium did not expect from traditional exhibits what their counterparts had when being introduced to the old National. In the Design phase a detailed strategy was developed, storyboarding, scripting and content development which were formulated according to the zoo's objective of protecting species. The film was meant to cater a large number of audience, thereby to be both interesting and valuable for families, school groups, and guests.

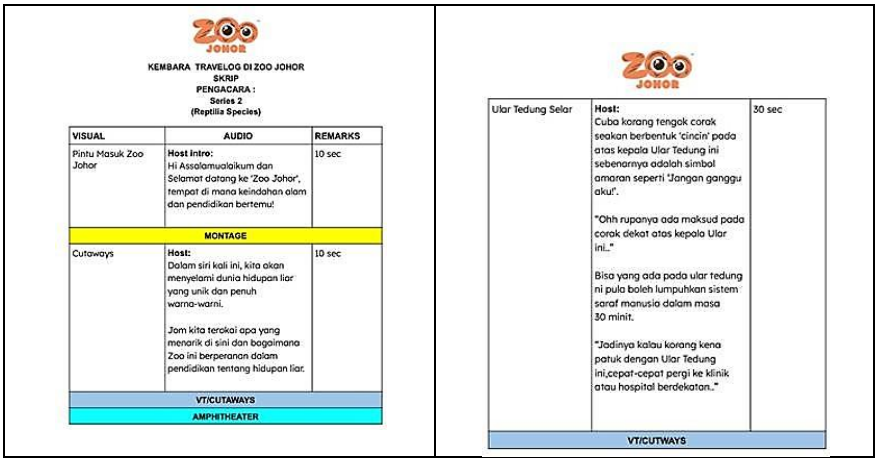
The Implementation phase was characterised by the travelogue video that was created by the team that rode up to Zoo Johor to film animal behaviours, interview people and showcase their efforts in conservation. Careful editing has been applied to create a lively educational narrative with attractive visuals, background music and voice covers. In terms of the operation phase, the movie was posted on the zoo's website and social media as a way to reach a bigger audience. To evaluate the impact of the video to the engagement and learning outcomes, we conducted visitor surveys. These results allowed us to improve the film for its film making of its film. This study used a quantitative methodology in which the survey tool used is online, passed on via Google forms and Physical questionnaires, for a sample size of 31 individuals aged between 18yrs – 55yrs and others. Convenience sampling technique was utilised in selecting the participants whereby individuals could be selected because they were readily accessible and eager to participate (Etikan, Musa & Alkassim, 2016). The constructs that the poll examined are instructional content, visitor engagement, multimedia components, usability and accessibility, and the overall visitor experience. The study was conducted using SPSS to gather and examine the data and mean values together with percentages were used to answer the study's research questions and achievement of research objectives.

3.0 RESULTS AND DISCUSSION

This travelogue video project of Zoo Johor developed in three stags that are preproduction, production and post production. When conducting the pre-production stage, the main aspect to do was in planning the entire structure and content of the video. The effort that went into scripting and storyboard was very detailed so that I could create education and engaging video for the audience.

Series	Species	Animal
1	Mammalia	Lembu Bali
		Kambing Pigmi
		Unta
2	Reptilia	Buaya
		Baning Perang
		Ular Sawa
3	Primet	Cimpanzi
		Monyet Kapusin
		Ungka Borneo
4	Avian	Merak India
		Burung Pegar Perak
		Kasuari Selatan

Figure 2: List of series and animals in the travelogue



KEMBARA TRAVELOG DI ZOO JOHOR
SKRIP
PENGACARA :
Series 2
(Reptilia Species)

VISUAL	AUDIO	REMARKS
Pintu Masuk Zoo Johor	**Host Intro:** Hi Assalamualaikum dan Selamat datang ke 'Zoo Johor', tempat di mana keindahan alam dan pendidikan bertemu!	10 sec
MONTAGE		
Cutaways	**Host:** Dalam siri kali ini, kita akan menyelami dunia hidupan liar yang unik dan penuh warna-warni. Jom kita terokai apa yang menarik di sini dan bagaimana Zoo ini berperanan dalam pendidikan tentang hidupan liar.	10 sec
VT/CUTAWAYS		
AMPHITHEATER		

Ular Tedung Selar	**Host:** Cuba korang tengok corak seakan berbentuk 'cincin' pada atas kepala Ular Tedung ini sebenarnya adalah simbol amaran seperti 'Jangan ganggu aku'. "Ohh rupanya ada maksud pada corak dekat atas kepala Ular ini.." Bisa yang ada pada ular tedung ni pula boleh lumpuhkan sistem saraf manusia dalam masa 30 minit. "Jadinya kalau korang kena patuk dengan Ular Tedung ini,cepat-cepat pergi ke klinik atau hospital berdekatan.."	30 sec
VT/CUTWAYS		

Figure 3: Scriptwriting

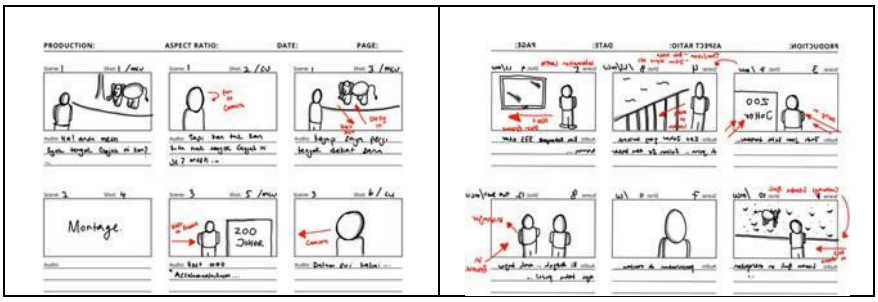


Figure 4: Storyboard

Creation of the Zoo Johor travelogue film is done in 3 main steps which are pre – production, production and post production. As each step was completed, they helped in the fulfilment of the education and engagement goals. Realizing that the project was to take place in the pre production stage, the first thing I did was to create a storyboard (Figure 4). The storyboard became a complete visual plan which included the content of the video and sequences also in a way that these sequences matched the educational goals. The important events that had occurred in each series were listed (such as the introduction of different animal species, mammals (Bali Cattle, Pygmy Goat, and Camel), reptiles (Crocodile, Waran, Python), primates (Chimpanzee, Capuchin Monkey, Bornean Orangutan), and birds (Indian Peacock, Silver pheasant, Southern Cassowary) Figure 2). The careful writing of the story made the video flow well, going from introducing animals to showing their behaviours and conservation efforts. Writing scripts was a crucial part of this stage, ensuring that the lessons were both enjoyable and informative. The script (Figure 3) was written to make animal facts and conservation messages exciting and easy to grasp. This way, viewers, especially younger ones, would remember what they saw.

During the Production phase, the team filmed the zoo's exhibits and animals and spoke with staff members. The focus was on recording how visitors and animals behave, utilizing both engaging graphics and informative content. Utilizing professional filming techniques, such as varied camera angles, consistent framing, and creative lighting, brought the concept and story to life. During post-production, the raw footage was edited together to create a single video. The movie utilized graphics and voiceovers to enhance the learning experience. These pieces reinforced necessary signals and provided additional information about the zoo's animals and conservation efforts. The movie was shared online, on social media, and on Zoo Johor's

website. This allowed it to reach more people than just those who went to the zoo in person. Visitor responses confirmed that the film was effective in increasing engagement, with many people stating that they enjoyed the dynamic story and found the information helpful.

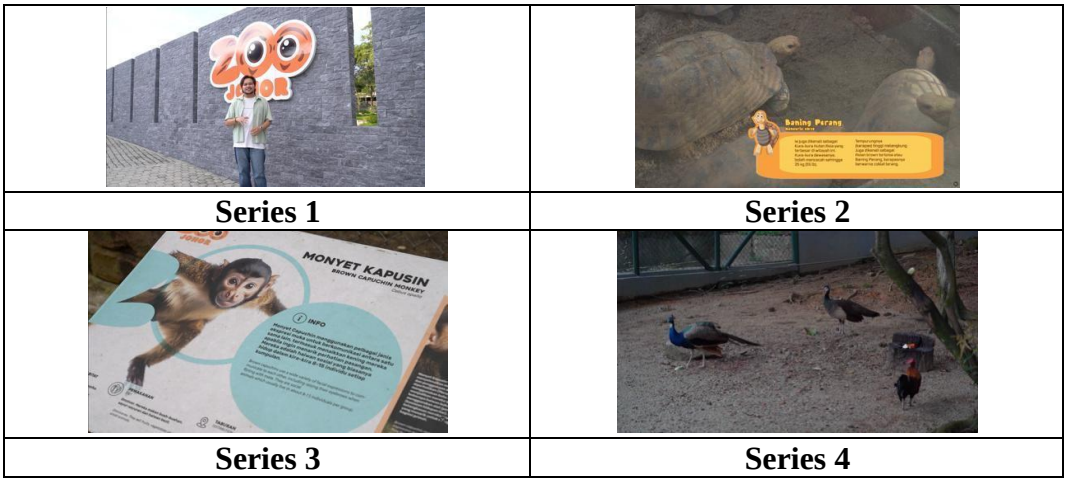


Figure 5: Result of travelogue video

The research topics that guided the effort are consistent with the study's conclusions. The data were analyzed to determine, characterize, and evaluate viewers' utilization of the Zoo Johor travelogue video as an educational resource. A self administered questionnaire was administered to 31 respondents (n = 31) such as general public and visitors at Zoo Johor and collected data were included. The Google Forms version of the questionnaire was used to gather respondents' data, which was then transformed to the SPSS data format for analysis. Therefore, it used a four point Likert scale that was originated by Rennis Likert in 1932, in assessing how well the viewers liked the travelogue film (as a medium) for engagement and instruction. Cronbach's alpha test produced highly reliable scores (0.912) which showed highly reliable and valid results.

Several important factors affecting the visitor experience on educational content in Zoo Johor were found through the study. Something that was very important was how the visitors were in it and the travelogue film held their attention the whole time. For instance, this demonstrates how better than basic, yet static displays, dynamic, multimedia substance will keep aficionades attracted more. The other important thing was that how well education content worked. This film was useful as well as memorable and by giving the visitors accurate and useful information, it also helped them to learn about biodiversity and wildlife protection. The educational experience was reached through visuals, narration and music. The content was more engaging as a result of these features, as the visitors could learn and even connect to the zoo's conservation work. The reason why visitors were pleased was because it was emotional and they felt it was their responsibility to look after wildlife. Moreover, the ability of people to watch the movie on a platform of their own choosing made the process easy and fun for every kind of visitor. All of these things show how interactive and multimedia tools can change standard teaching techniques into more interesting and useful ones.

The information gathered from the first study question was looked at using means and percentages. This study classified viewers' utilization of the Zoo Johor travelogue film as an educational resource into three tiers: low, moderate, and high. A mean score between 1.00 and 2.00 indicated a low level of acceptance, a mean score between 2.10 and 2.99 indicated a moderate level and a mean score between 3.00 and 5.00 indicated a high level. Table 1 shows

the results of the descriptive analysis. The results show that many people who watched the Zoo Johor travelogue movie liked it as a way to promote and educate.

Table 1: Mean and level value

Mean	Levels
3.00 to 5.00	High
2.10 to 2.99	Moderate
1.00 to 2.00	Low

Table 2: Demography

Items	Frequency (N=31)	Percent 100%
Age		
Under 18	13	41.9
18-24	13	41.9
25-34	3	9.7
35-44	2	6.5
45-54	-	-
55 and above	-	-
Under 18	-	-
Total	31	
Gender		
Male	17	54.8
Female	13	41.9
Non-Binary	-	-
Prefer Not to Say	-	-
Total	31	
Frequency of Visits to Zoo Johor		
First-time Visitor	15	48.4
Occasional Visitor (1-2 times a year)	9	29.0
Frequent Visitor (3+ times a year)	6	19.4
Total	31	
Nationality		
Malaysian	30	96.8
International Tourist	-	-
Total	31	
Education Level		
High School	18	58.1
Undergraduate Degree	9	29.0
Postgraduate Degree	2	6.5
Total	31	

The demographic data from the survey respondents indicates that the majority of participants were under the age of 18 and between the ages of 18 and 24, with each group accounting for 41.9% of the total respondents. Smaller categories included 25-34 (9.7%), 35-44 (6.5%), and 45-54 (6.5%), while 55-plus was not represented. There were 54.8% male respondents, 41.9% female respondents, and no respondents who identified as non-binary. 48.4% of Zoo Johor

visitors were first-time, 29.0% were infrequent (1-2 times a year), and 19.4% were frequent (3+ times a year). Only 3.2% were overseas tourists; 96.8% were Malaysian. 58.1% had graduated high school, 29.0% had an undergraduate degree, and 6.5% had a postgraduate degree.

Table 3: Educational content

Items	Mean	Interpretation
The travel video effectively conveyed educational messages about wildlife conservation.	4.58	High
The information provided in the travelogue video was relevant and valuable for learning about animal species at Zoo Johor. (Mamalia, Reptilia, Primet & Avian)	4.74	High
The video improved my understanding of the importance of biodiversity and wildlife preservation.	4.35	High
The educational content in the video was accurate and credible.	4.65	High
I learned something new about animal conservation through the travelogue video.	4.52	High

The Zoo Johor travelogue video's educational content survey showed high viewer satisfaction and engagement. Wildlife conservation was educated by the video to the viewers with a mean value of 4.58, which implied that viewers had good agreement. I learnt about Zoo Johor's mammals, reptiles, primates and birds the most from the travelogue movie which scored 4.74. There was a significant improvement in viewers' knowledge of biodiversity and wildlife preservation with a mean score of 4.35. It was extremely accurate and credibile educational information which gave it a score of 4.65. Furthermore, the 4.52 score also shows that viewers got to learn something new about animal conservation from the travelogue. Its instructional goals indicate that travelogue video attained these goals.

Table 4: Visitor engagement

Items	Mean	Interpretation
The travelogue video kept me interested throughout its duration.	4.52	High
I felt emotionally engaged while watching the travelogue video.	4.55	High
The video encouraged me to learn more about wildlife conservation after I visited Zoo Johor.	4.58	High
The content in the video sparked my curiosity about animal species.	4.39	High
I recommend watching the travelogue video to others visiting Zoo Johor.	4.58	High

Excellent audience engagement and satisfaction towards the Zoo Johor travelogue film is found in the survey findings. The film figured a mean score of 4.52, signifying that watchers were involved in consistently the film. In addition, a mean score of 4.55 on emotion resulted on feeling emotionally linked with video viewers. At Zoo Johor, the film scored high mean with a score of 4.58 which encourages the visitors to learn about protection of the wildlife. The content appeals viewers with regards to the species of animal at a rating of 4.39 and they

will be willing to spread the content word out by recommending the film to visitors of Zoo Johor with a rating of 4.58. Through these findings, it can be shown that the travelogue film was able to involve the viewers and motivate them in wildlife conservation as well as in the preservation of animal species.

Table 5: Multimedia elements

Items	Mean	Interpretation
The use of multimedia elements (e.g., music, visuals, narration) enhanced my learning experience in the video.	4.81	High
The video provided an immersive experience that helped me gain a deeper understanding of the zoo's conservation efforts.	4.83	High
The video's use of visuals and sounds made the educational content more memorable.	4.45	High
I felt a deeper connection to the animals and conservation efforts through the multimedia elements in the video.	4.61	High
The use of multimedia elements (e.g., music, visuals, narration) enhanced my learning experience in the video.	4.45	High

The Zoo Johor travelogue film was then surveyed to determine its multimedia features which helped to increase the viewer's happiness and learning. Multimedia based with music, graphics and narration had improved learning when compared with the mean score of 4.81. The mean score of 4.83 in the video (the highest in the table) depicts Zoo Johor's conservation efforts in immersing rather than passively communicating the information. Educational things that had sights and audio in the videos scored 4.45 on average. The mean score of multimedia features helped viewers to link to animals and conservation activities was found to be 4.61. This shows that educational multimedia content is more engaging, more memorable and it has a greater emotional impact.

Table 6: Usability and accessibility

Items	Mean	Interpretation
The video was easy to understand.	4.58	High
The video was accessible and usable across various devices (e.g., mobile, desktop).	4.48	High
The video loaded quickly and without errors on all platforms I used.	4.48	High
I found the educational content presented in the video easy to navigate and understand.	4.48	High
The video was easy to understand.	4.48	High

The Zoo Johor travelogue video's usability and accessibility indicate excellent satisfaction across platforms. The video's high mean score of 4.58 indicated that respondents found it clear and accessible. The video's accessibility and usability across mobile and desktop devices received a mean score of 4.48. The video loaded swiftly and correctly on all platforms, scoring

an average of 4.48. Another mean score of 4.48 showed that viewers found the video's educational content easy to access and understand. These results show that the film was easy to watch and beneficial for many people.

Table 7: Overall visitor experience

Items	Mean	Interpretation
The travelogue video improved my overall experience at Zoo Johor.	4.68	High
The video made me more interested in visiting Zoo Johor.	4.58	High
The travelogue video makes a positive contribution to Zoo Johor's conservation and education efforts.	4.48	High
The video made me feel more connected to Zoo Johor's mission of wildlife conservation.	4.48	High
Let other zoos implement similar travel videos to educate their visitors.	4.58	High

The Zoo Johor travelogue video survey showed excellent visitor satisfaction. With a high mean score of 4.68, the video improved viewers' experience. With a mean score of 4.58, the video enhanced interest in the Zoo Johor tour. This indicates that the video engaged viewers. The mean score of 4.48 indicated that respondents believed the video contributed to Zoo Johor's conservation and education efforts. Again, the video scored 4.48 for connecting viewers to the zoo's wildlife conservation purpose. Many respondents advised that other zoos use similar travelogue recordings, with a mean score of 4.58, indicating that the video was enjoyable and educational.

Table 8: Mean and level scores of each element.

Item	Mean	Level
Educational content	4.56	High
Visitor engagement	4.52	High
Multimedia elements	4.62	High
Usability and accessibility	4.50	High
Overall visitor experience	4.56	High

The survey found that viewers liked all aspects of the Zoo Johor travelogue video. The video's educational element scored 4.56, suggesting that it effectively communicated conservation messages. Site engagement was also good, with a mean score of 4.52, indicating that the video engaged viewers. Multimedia scored the highest, with a mean of 4.62, indicating that pictures, narrative, and sound enhance learning. The video was straightforward to navigate and accessible across platforms, with a 4.50 usability and accessibility rating. The travelogue film also improved the zoo's visitors' involvement, education, and enjoyment, with a mean score of 4.56.

4.0 CONCLUSION

The Zoo Johor travelogue film successfully captivated viewers and achieved its educational goals. It garnered elevated ratings in all aspects, with multimedia components (mean score of 4.62) and instructional content (mean score of 4.56) being especially effective in conveying conservation messages. It was actually very engaging to visitor (4.52) and readily available and user friendly as well (4.50). The film made a large difference in tourist experience (4.56) by making the link between Zoo Johor's conservation initiatives stronger. Research suggests that the travelogue film is able to educate and engage zoo visitors as a model for other zoos to adopt and illustrate the ability of travelogue movies to facilitate visitor engagement and a better learning experience. Additionally, this information is quite useful to other zoos that also want to advance teaching programs by using multimedia materials.

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Designing a Promotional Interactive Website for JBEES Johor: Empowering Stingless Bee Entrepreneurs

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ABSTRACT

This study focuses on the development of a promotional interactive website for Persatuan Usahawan Lebah Kelulut Johor (JBEES). The research addresses the lack of effective marketing, which hinders the growth of local beekeeping entrepreneurship. The objectives include identify effective strategies for introducing the "Persatuan Usahawan Lebah Kelulut Johor" (JBEES) to the public in Johor, develop a user-friendly service website tailored to the needs of clients and local stingless bee honey businesses collect and, analyses public feedback regarding the effectiveness and reception of the new media applications integrated into the website. The problem statement highlights challenges such as outdated promotional platform by using social media as advertising strategies, the low public interest in stingless bee farming, and the low members in the stingless bees business organization. Through qualitative and quantitative methods in surveys, interview questions, and observation. This study examines JBEES's current business practices, self-branding strategy, and user interface. Key findings reveal the need for a modern, interactive website to enhance visibility, educate users, and foster direct interaction between beekeepers and consumers. In addition to showcasing the JBEES purpose and recent accomplishments, the promotional interactive website employs design thinking, eye-catching graphics, and intuitive navigation to draw in joining the JBEES organization. According to the study, creating a functional digital platform may significantly increase JBEES's reach, promote local business owners, and guarantee that stingless bee honey is acknowledged, by establish stingless bee honey as a flagship Malaysian product, ultimately contributing to the industry's sustainability and growth.

Keywords: interactive website, promotional, agro-entrepreneurship, JBEES, digital engagement.

1.0 INTRODUCTION

1.1 Inroduction

The research focuses on the development of a promotional interactive website for Persatuan Usahawan Lebah Kelulut Johor (JBEES), a non-governmental organization dedicated to advancing Johor's stingless bee honey industry. Despite JBEES's efforts, the sector faces challenges such as limited marketing reach, low public awareness, and a lack of engagement, particularly among younger generations. This study aims to address these issues by creating a user-friendly website that enhances visibility, educates users, and fosters direct interaction between beekeepers and consumers. Through qualitative and quantitative methods, including observations, interviews, and questionnaires, the research identifies effective strategies for promoting JBEES, designs an intuitive digital platform, and evaluates public feedback. The findings highlight the importance of interactive features, clear branding, and trust-building elements in driving interest in agro-entrepreneurship. Ultimately, the project seeks to position stingless bee honey as a flagship Malaysian product, contributing to the industry's sustainability and growth while empowering local entrepreneurs.

1.2 Background Research

JBEES Promotional Interactive Website project explores the need for a modern, engaging digital platform to support stingless bee honey entrepreneurs in Johor, Malaysia. Persatuan Usahawan Lebah Kelulut Johor (JBEES) is a local NGO aiming to make Johor a central hub for stingless bee honey production in Southeast Asia (johobees.com). However, the industry faces challenges including infrastructure, public ignorance, adulteration stingless bee honey controversy, and a lack of digital advertising. Which leading many beekeepers to treat it as a side activity instated on business opportunity (Rosmiza et al., 2020). From a research perspective, improving corporate design in order to highlight their hard work, innovations, and commitment to agro-entrepreneurship, thereby enhancing JBEES's promotion and attracting investors by solving JBESS key challenges: 4P strategy in plantation management, entrepreneurial upgrading, market development, and scientific advancement (johobees.com). The platform uses design thinking, semiotics in branding, and responsive interfaces to attract younger generations, showcase Malaysian stingless bee honey as its main product, and ensure the growth of the local beekeeping sector (Wan Ismail, W. I. (2016).

1.3 Problem Statement

The primary problem faced by the JBEES project is the lack of an effective digital promotional platform to support and expand the stingless bee honey industry in Johor. Although JBEES has been promoting their effort with local beekeepers for over a decade, in uniting and empower local beekeepers through Facebook and blog. It did not present well as it been shows how weak online presence and inconsistent corporate design further diminish its credibility compared to competitors (johobees.com). The organization also struggles to attract younger generations and new agro-entrepreneurs due to a weak online presence and underutilization of modern interactive media platforms (Abdullah, R., (2024). The majority of beekeepers treating the industry as a sideline, thus, JBEES urgent need for a robust digital platform to build consumer trust, enhance market competitiveness (Rosmiza et al., 2020). By increasing public awareness, presenting its mission, showcase its achievements, or build lasting relationships with potential stakeholders (Soh et al., 2021). Therefore, a strategic promotional website is essential to elevate JBEES's visibility, credibility, and outreach.

1.4 Purpose of Promotional Interactive Website

The purpose of developing the Promotional Interactive Website for JBEES is to establish a dynamic digital platform that effectively promotes Johor's stingless bee honey industry while supporting local agro-entrepreneurs. This website aims to increase public awareness of the JBEES organization and encourage participation in the industry, especially among younger generations (Bernama. (2020, January 3). By providing an engaging, user-friendly interface, the platform will facilitate direct interaction between consumers and beekeepers, fostering trust and transparency. It serves as an educational hub, offering information about stingless bee farming, product authenticity, and JBEES's achievements. The website also functions as a branding tool, strengthening JBEES's identity through visually appealing design and strategic messaging (Jevremović, M., (2022). It enables access to certified honey and entrepreneurship programs, enhancing the user experience and promoting local economic growth. Additionally, the site will integrate interactive features such as call-to-action prompts and responsive layouts to optimize digital engagement. Ultimately, the website will support JBEES's mission to position stingless bee honey as a flagship Malaysian product while driving industry sustainability and innovation.

1.5 Research Objectives

i. To identify effective strategies for introducing the "Persatuan Usahawan Lebah Kelulut Johor" (JBEES) to the public in Johor
ii. To develop a user-friendly service website tailored to the needs of clients and local stingless bee honey businesses.
iii. To collect and analyse public feedback regarding the effectiveness and reception of the new media applications integrated into the website.

2.0 METHODOLOGY

2.1 Research Methodology

The research methodology for the JBEES Promotional Interactive Website project adopts a mixed-methods approach, combining both qualitative and quantitative data collection to ensure comprehensive insights. The study begins with qualitative research, including interviews with JBEES members, local beekeepers, and consumers to gather in-depth perspectives on existing promotional challenges and website expectations. Observational research is conducted on JBEES's current online platforms, such as Facebook and blogs, to assess their effectiveness and limitations. Quantitative methods are applied through structured questionnaires distributed to 60 participants, primarily targeting individuals in Johor interested in stingless bee entrepreneurship. The questionnaire focuses on user interface (UI), user experience (UX), design appeal, and content clarity. The project follows a three-phase production cycle: pre-production (literature review, competitive analysis, and planning), production (website development, content creation, and design integration), and post-production (usability testing, data analysis, and refinement). Tools like SPSS are used to analyse survey data, ensuring statistically sound conclusions. This methodological framework ensures the final website aligns with user needs, JBEES's objectives, and digital branding best practices.

3.0 RESULTS AND DISCUSSION

3.1 Promotional Interactive Website Development

The result of the JBEES Promotional Interactive Website project demonstrated a successful development of a user-centered digital platform aimed at increasing awareness and engagement in the stingless bee honey industry. The final website design had a responsive layout, easy navigation, a visually appealing logo and colors, and call-to-action options for both desktop and mobile viewing. A prototype launch review collected with 66 respondents from online questionnaire survey and using SPSS version 27 in analysis data respondent, demonstrated a considerable good reception. From responded survey shows:

According to the survey findings, 80.3% of respondents thought the website's images and design correctly reflected JBEES' work with stingless bee businesses. Meanwhile, 18.33% of participants remained neutral on the depiction, while 6.82% thought that the website did not accurately represent JBEES' activities. Furthermore, 45.91% of respondents said they didn't think the graphics were perfect, suggesting areas where JBEES may improve in presenting the entire breadth of its work.

Table 3-1 Product Knowledge

a) How well did the website's imagery and graphics represent JBEES' work with stingless bee entrepreneurs?

		Frequency	Percent	Valid Percent	Cumulative Percent	Total percentage
Valid	Perfect representation	20	30.3	30.3	30.3	45.91%
	Good representation	35	53.0	53.0	83.3	80.30%
	Neutral	8	12.1	12.1	95.5	18.33%
	Poor representation	3	4.5	4.5	100.0	6.82%
	Total	66	100.0	100.0		

Additionally, 89.55% of respondents preferred websites with interactive features such as animations and videos. However, 57.42% stated that they do not want these interactive components to be added to websites. Furthermore, 4.55% of respondents were confused whether interactive features such as animations and videos are required on a website.

Table 3-2 Element Aesthetical In UI

b) Do you prefer websites with interactive features (e.g., animations, videos)?

		Frequency	Percent	Valid Percent	Cumulative Percent	Total percentage
Valid	Yes	39	59.1	59.1	59.1	89.55%
	No	25	37.9	37.9	97.0	57.42%
	Maybe	2	3.0	3.0	100.0	4.55%
	Total	66	100.0	100.0		

In terms of emotional response, 55.15% of users said they felt inspired, motivated, intrigued, or engaged while exploring the website. However, 36.67% of respondents felt ambivalent about their experience. In addition, 4.55% of users indicated annoyance because they were confused how to navigate or use particular site functions.

Table 3-3 Element Functionality In UX

c) How would you describe your overall emotional response while using the website?

		Frequency	Percent	Valid Percent	Cumulative Percent	Total Percentage (%)
Valid	Inspired/ Motivated	24	36.4	36.4	36.4	55.15%
	Interested/ Engaged	24	36.4	36.4	72.7	55.15%
	Neutral	16	24.2	24.2	97.0	36.67%

	Frustrated	2	3.0	3.0	100.0	4.55%
	Total	66	100.0	100.0		

Furthermore, 57.42% of respondents said they felt linked to the JBEES community's achievements and hard work, demonstrating the website's ability to generate emotional engagement. Meanwhile, 48.18% agreed slightly with the sentiment, while 36.67% remained neutral. On the other hand, 6.82% moderately disagreed, claiming that the website did not appropriately showcase the community's achievements and hard work, and 2.27% strongly disagreed, believing that the site did not place enough focus on these accomplishments.

Table 3-4 Element Functionality in UX (User Experience) After Visiting the Website

d) I feel connected with the achievements and hard work of JBEES community

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**	**Total Percentage (%)**
Valid	Disagree	1	1.5	1.5	1.5	2.27%
	Moderately Disagree	3	4.5	4.5	6.1	6.82%
	Neutral	16	24.2	24.2	30.3	36.67%
	Slightly Agree	21	31.8	31.8	62.1	48.18%
	Agree	25	37.9	37.9	100.0	57.42%
	Total	66	100.0	100.0		

4.0 CONCLUSION

The JBEES Promotional Interactive Website successfully answered the organization's demand for a modern digital platform, as indicated by the survey findings. The vast majority of users (89.55%) favored interactive features such as animations and movies, emphasizing the value of engaging material. Furthermore, 80.30% of respondents said the website accurately depicted JBEES's work, with 18.33% remaining neutral, indicating space for improvement in visual depiction. Emotional engagement was high, with 55.15% reporting emotions of inspiration or motivation and 36.67% feeling neutral, demonstrating a range of user experiences. Notably, 57.42% of consumers felt linked to JBEES' successes, whereas 36.67% were neutral and 6.82% disapproved, indicating the need for improved storytelling. The website's responsive design and straightforward navigation were well appreciated, with only 4.55% expressing irritation, demonstrating its user-friendliness. These data illustrate the platform's efficacy in increasing awareness, trust, and engagement, which aligns with JBEES' goals. However, the mixed responses suggest areas for improvement, notably in material clarity and emotional appeal. Overall, the initiative demonstrates the importance of interactive digital branding in fostering agro-entrepreneurship, with the potential to enhance user experience and community engagement.

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Developing A Virtual Reality-Based 3D Simulation Representing The Environment And Features Of Taman Negara Johor Tanjung Piai

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ABSTRACT

The project is developing a basic 3D simulation and VR app that is meant to show the mangrove forest area in Taman Negara Johor Tanjung Piai. With Autodesk Maya used for modeling the simulation in 3D and Unity 6 for interactive deployment, anyone can use it to understand the species and overall construction of mangrove habitats. You should strive to identify important 3D elements, develop a VR simulation and check how efficient it is as a teaching tool. The evaluation was done using surveys, observing the users and conducting interviews with the visitors and employees of Taman Negara Johor Tanjung Piai to assess the simulation, how easy it is to use and whether it helped in learning; the results were used for further improvements and progress to ensure it achieves its goals and matches user expectations. Improvements were included in the simulation by going through Autodesk Maya and Unity 6 development stages and following the comments offered. Even with a simple design, the simulation displays important parts of the ecosystem using 3D models and points where things can be affected. With VR headsets, it offers a distractionless place for users to concentrate and gain practical experience. The project proves that VR is a flexible and modern tool for digital learning and involving the public, allowing them to explore nature in a meaningful way.

Keywords: 3D simulation, environmental education, virtual reality, interactive learning, landscape visualization

1.0 INTRODUCTION

1.1 Introduction

3D modeling has taken on a broad range of important roles because of its powerful abilities. As revealed by Gill's work of 2013, three-dimensional models are excellent for displaying and reviewing landscape design and urban planning proposals. These models help people involved in the process see and study the proposed environmental changes, leading to better understanding and choices (Bilge, 2018). Also, Bilge (2018) found that letting users view and respond to 3D visualizations on their phones leads to a greater role for everyone in planning and design matters. As well as urban design, 3D modeling is important in managing natural resources and teaching. He talks about how 3D models and virtual reality are used in forestry for activities such as managing forests, training people and interacting with stakeholders. These technologies let users examine complex ecosystems from many directions and easier understand their spatial connections. In addition, research carried out by Castro et al. (2021) proves that 3D models help students achieve better results and are more motivated in school.

Due to the biodiversity in its lands, Taman Negara Johor Tanjung Piai demonstrates the value of 3D modeling perfectly. Thanks to this technology, interactive and visual representations of the park's mangroves, seashores and dry land areas could be made. Jerez Nova's study (2022) shows how we can use 3D modeling for analyzing how mangroves affect waves. These 3D models would be beneficial for a range of reasons in the Taman Negara Johor Tanjung Piai.

With the aid of modelers, it would be easier to keep track of and evaluate how the environment and human activities are affecting the area. They can use these models in their studies of the park's diversity, how its ecosystems function and its geological features. Interactive models could also improve the visitor's journey by allowing them to explore the grounds and the wildlife from inside their homes.

3D modeling provides a new way to look at, grasp and involve oneself with our environment. The focus of landscape architecture is present in several areas such as landscape design, urban planning, forestry, teaching and nature conservation. With better 3D modeling and the help of GIS and environmental technologies, there are new opportunities for studying, organizing and taking decisions. Adopting 3D modeling in Taman Negara Johor Tanjung Piai can lead to better results in conservation, studies, learning and interactions with the public. Improvements and applications of 3D modeling are sure to follow as technology keeps advancing which will aid in the management and knowledge of our resources.

1.2 Background Research

Using 3D modeling in landscape architecture and urban planning has become popular and has made it much easier to turn design proposals into ideas people can see and understand. According to Gill (2013), 3D models can make it simpler for stakeholders to grasp and react to potential changes by offering them interactive and secure views of what is proposed. Bilge (2018) suggests that people gain better access to taking part in planning and design activities because of 3D visualizations on mobile devices. Apart from what it does for cities, 3D modeling is also used for managing resources and teaching in various fields. The author (Perez-Huet in 2020) studies the application of virtual reality (VR) and 3D simulations in the field of forestry for various tasks such as forest management, restoration therapy, education, interaction with stakeholders and training. With these technologies, people can experience and understand complicated forest ecology in a smarter and more engaging way. In addition, Castro et al. (2021) mention that learning with 3D objects can make biology easier to learn and motivate students. 3D models make it possible for students to examine and modify difficult elements and processes which helps them gain a stronger understanding and interest in what they are learning.

Since Taman Negara Johor Tanjung Piai has a unique biodiversity and many different ecosystems, it offers a promising opportunity to use 3D modeling. Jerez Nova's research (in 2022) of modeling mangrove vegetation shows how 3D technology can help with environmental studies and handling. For Taman Negara Johor Tanjung Piai, models in 3D can show the park's different areas, for example, its mangroves, coastlines and land-based ecosystems. Such models will help stakeholders to anticipate the outcomes of various methods of land-use and development, so they can plan and manage conservation tasks more effectively. Also, showing 3D models of the park to visitors can help them enjoy the outdoors and better appreciate everything the park has to offer.

Using 3D modeling in landscape design, managing the environment and teaching brings improvements in visualizing, communicating and engaging with projects. What is shown in these articles demonstrates that 3D modeling can foster involvement in city planning, allow for better educational results and help with comprehensively managing natural resources. Applying 3D modeling to Taman Negara Johor Tanjung Piai is expected to boost conservation, teach about the environment and inform people about this important ecosystem.

1.3 Problem Statement

Although 3D technology is improving in simulations and education, using it in Malaysia's protected areas like Taman Negara Johor Tanjung Piai is still very limited. Because of the important mangrove areas and its place as the southernmost point on the continent, this national park can use digital media to educate the public and raise awareness of the environment. The present tools for informing the public about the park's ecological and cultural value are mostly fixed, depend much on words and need new ways to present the information. Many young people are not interested in the park's information because it is still mainly shared through traditional things like brochures, signboards and maps. In Gill's view (2013), interactive 3D models and similar tools allow people to enjoy and better access detailed information about environmental and geographical topics. For this reason, learning tools are rarely used in public parks and educational environments, so people miss out on chances to improve how they learn and interact.

3D modeling and virtual simulations have brought about huge improvements in learning and school results for others, but Taman Negara Johor Tanjung Piai is not using them well. Visitors are unable to discover through activities how mangrove trees help the environment in different ways. According to Bilge (2018), on-site mobile technology is important for involving visitors, but this is not well implemented within the park today. Also, as a result, those with special needs and people carrying out remote studies are not included, making environmental education harder for them. Offering interactive 3D simulations might help fill this gap because they display the mangrove ecosystem in a way that meets the needs and expectations of many different learners. Using only a small amount of new media resources and fewer experiences with the site has made it difficult for people to learn about why Taman Negara Johor Tanjung Piai needs to be preserved. Thus, it is necessary to use modern educational tools, like 3D simulation, to improve students' engagement and commitment to taking care of nature.

2.0 METHODOLOGY

This project adopted a mixed-method approach involving both qualitative and quantitative strategies used in this project to determine the effect of a 3D VR simulation of Taman Negara Johor Tanjung Piai. The landscape of the mangrove ecosystem was modeled in detail using Autodesk Maya and then Unity was used to design and develop it into a virtual reality (VR) simulation. Data from both surveys and watching users was gathered to analyse the experience of users, what they understood about mangrove ecology and what they learned. More information and opinions were gathered by speaking with staff members and educators in the park during interview sessions. Information from how users interacted and their responses helped improve the tool and confirm its educational effect.

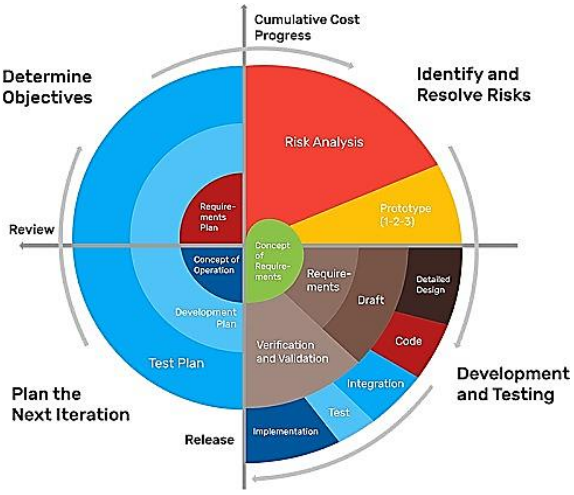

Figure 1 Spiral Model

The "Spiral Model" approach was used to make the 3D VR simulation which means planning, designing, prototyping and evaluating were done in several iterations. Because of this method, the software could be updated all the time, using information from users and risk assessments. Every update was aimed at enhancing the 3D models and how VR works, making sure the simulation was useful and accurately depicted what users would see in Taman Negara Johor Tanjung Piai.

3.0 RESULTS AND DISCUSSION

The development of the 3D VR simulation resulted in a functional, low-fidelity interactive environment that successfully replicated key elements of Taman Negara Johor Tanjung Piai's mangrove landscape. Many participants mentioned that using the simulation helped them better understand mangroves, what they do in the ecosystem and why it is important to conserve them. Most students showed satisfaction with the way the archaeological findings were displayed and the educational information given. According to the interviews, the simulation helps in tourism and gives students extra learning resources. They suggest that VR technology supports environmental education and also reveal chances to make it better such as through improved interaction and bigger stories.

These data were gathered by respondents who participated in assessing the effectiveness of the 3D VR simulation in Taman Negara Johor Tanjung Piai. To make the results clear, the mean scale interpretation method is employed to review the research on the effectiveness and functionality of the 3D VR simulation. A five-point Likert scale is used for collecting the data which gives participants the option to say Very Low, Low, Medium, High or Very High. It is an easy way to pick up on users' responses and analyze the simulation's overall outcome.

Table 1: Interpretation of Mean Score

Mean Score	Interpretation
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.20	Medium
3.21 – 4.20	High
4.21 – 5.00	Very High

Table 2: Usability and Interaction

Item	Mean	Interpretation
How easy was it to navigate the VR simulation?	4.40	Very High
Were the controls intuitive and easy to use?	4.55	Very High
Did you experience any discomfort while using the VR simulation?	3.65	High
Did you feel in control while navigating through the simulation environment?	4.85	Very High
Was the response time smooth and without delay?	4.70	Very High

Most participants rated the simulation very positively, finding navigation easy, the controls intuitive and the sense of control and response time very satisfactory, scoring all these aspects between 4.40 and 4.85. This proves users found it easy to use and interact with the system which made their experience better. Even though most replies were very positive, the discomfort reported was lower, with a mean score of 3.65 marked as “High,” meaning a few users felt some slight discomfort. All in all, the findings reveal good user satisfaction and effective VR design.

Table 3: Visual and Audio Quality

Item	Mean	Interpretation
How would you rate the visual quality of the 3D environment?	4.65	Very High
How engaging was the overall design of the mangrove ecosystem?	4.60	Very High
How effective were the audio elements?	4.55	Very High
Were the colours, textures, and details of the environment appropriate and appealing?	4.65	Very High
Did the visual and audio elements work well together to create a cohesive experience?	4.45	Very High

All the aspects related to the 3D version of the mangrove ecosystem scored extremely high marks because of its high-quality look and sound. They rated how attractive and believable the visuals, colors, textures and details are at 4.65 which indicates that the design looks impressive and natural. With 4.60 out of 5, the system’s design was also seen as being very appealing and interesting to the users. 4.55 points were given to audio features which largely contributed to the experience being enjoyable. It was rated 4.45 for how well visual and audio elements were integrated which confirmed that the combined sensory design helped attract users’ attention.

Table 4: Educational Impact

Item	Mean	Interpretation
Did the simulation help you understand the function of mangrove ecosystems?	4.70	Very High
After experiencing the simulation, are you more aware of environmental conservation issues?	4.30	Very High
Do you feel more interested in visiting or learning more about Taman Negara Johor Tanjung Piai?	4.75	Very High
Was the simulation content clear, informative, and easy to understand?	4.75	Very High

The simulation helped people learn about mangroves and conserve the environment, as all the topics achieved "Very High" ratings. The majority of participants thought the simulation helped them understand mangrove ecosystems, reaching an average score of 4.70. It also helped people sustain their attention to conservation concerns, showing an average of 4.30. Besides, the simulation made people more interested in Taman Negara Johor Tanjung Piai, as the mean score for wanting to visit or find out more was 4.75. The simulation was considered equally clear, informative and easy to understand which shows that it works well for education.

Table 5: Overall Experience

Item	Mean	Interpretation
How satisfied are you with the VR simulation experience overall?	4.80	Very High
Would you recommend this VR simulation to others?	4.80	Very High
If this simulation was improved and expanded, would you be interested in using it again?	4.85	Very High
Do you think the VR simulation can replace or complement real-life visits to the park?	4.35	Very High
How emotionally connected did you feel to the environment portrayed in the simulation?	4.10	High

Most users were very pleased with how VR simulation worked, rating it 4.80 overall and saying they want to recommend it to friends. A different version with additional features generated the highest level of interest at 4.85. In general, the participants had a positive opinion about the simulation's ability to either take the place of or support real hospital visits, rated by a mean of 4.35. Even though the level of emotional connection was at 4.10 which is only moderately lower, it still suggests a worthwhile yet reduced level of intense emotion for the players. All in all, the findings prove that people like using the simulation and that it can benefit learning and awareness in relation to conservation.

4.0 CONCLUSION

The project concludes that virtual reality 3D simulation helps to promote and inform about environmental topics and it is especially useful in ecologically important parts of Malaysia such as Taman Negara Johor Tanjung Piai. This low-fidelity virtual reality simulation for Taman Negara Johor Tanjung Piai has proven that it is still capable of engaging users, boosting education and helping save nature, provided it is well put together. In the future, adding better

interactivity, support for multiple languages and accessibility features could help the simulation teach more people. The project establishes a model that allows VR to be useful in other protected areas or national parks for sustainable tourism and educating the public about nature.

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Development of Augmented Reality at Zoo Johor to Promote Interactive Learning Experiences

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ABSTRACT

This study investigates the use of Augmented Reality (AR) to enhance visitor experiences at Zoo Johor through interactive and educational learning. In digital age, traditional informational tools such as static signage and printed brochures may no longer meet the expectations of modern visitors, particularly younger audiences accustomed to digital media. This lack of interactivity can limit visitor engagement and reduce the effectiveness of educational messages. To address this, the study focused on three objectives to identify key design elements of an effective AR application, to develop an interactive AR experience that incorporates zoo education content, and to evaluate user acceptance of AR as an educational tool for zoo experience. The research adopted a quantitative approach, using structured questionnaires distributed to visitors who tested a functional AR prototype featuring markerless AR and 3D animal models. The survey measured user responses across variables such as perceived ease of use, usefulness, satisfaction, and engagement. Descriptive statistical analysis was employed to assess patterns in user perceptions. The findings indicated high user satisfaction, with most participants agreeing that the AR application was engaging, easy to use, and enhanced their learning. Zoo education elements were particularly well received, making the content more memorable and meaningful. The study concludes that AR has significant potential to improve informal learning experiences in zoos and recommends further development and testing to assess its long-term educational impact.

Keywords: augmented reality, zoo education, visitor engagement, conservation awareness, educational technology

1.0 INTRODUCTION

In recent years, digital technology has rapidly transformed the way information is accessed, understood, and experienced in both formal and informal learning environments. Zoos, as informal educational spaces, serve a dual role in providing recreational value and promoting public understanding of wildlife and conservation. However, traditional informational tools such as static signage, printed brochures, and guided tours may no longer align with the expectations of modern visitors, particularly digital-native generations who are more attuned to interactive and immersive media. This disconnect often leads to reduced engagement and limited knowledge retention, especially in conveying complex ecological or conservation messages. As such, there is a growing need to explore innovative solutions that can enrich the zoo experience while supporting educational outcomes. Augmented Reality (AR), a technology that overlays digital content onto the physical environment, presents an exciting opportunity to bridge this gap. By making learning more interactive, visual, and personalized, AR has the potential to engage visitors in new ways and enhance their understanding of wildlife. This study investigates the development and implementation of an AR application for Zoo Johor, with a focus on integrating zoo education content into an engaging digital platform

that supports visitor interaction, learning, and conservation awareness.

1.1 Augmented Reality

The term "Augmented Reality" (AR) refers to a technology feature that is more than just a fad; it is transforming the way in which we perceive and engage with the world around us. The use of augmented reality (AR) makes learning more immersive and interactive by incorporating digital elements such as text, animations, and three-dimensional objects into real-world settings. In contrast to virtual reality, which completely replaces everything in your environment, augmented reality (AR) augments what is already present (Azuma et al., 2019). This opens up a new way to investigate information, particularly for individuals who can learn most effectively through observation and participation. According to Billinghurst and Duenser (2012), augmented reality has demonstrated in educational settings the potential to attract students' attention, pique their curiosity, and assist them in remembering what they see. Augmented reality (AR) not only makes learning more enjoyable for today's audiences, but it also makes it more effective. This is especially true for the younger generation, specifically those who have grown up with smartphones and apps.

1.2 Augmented Reality at Zoo Johor

Zoo Johor is one of Malaysia's oldest and most popular zoos, with fun and educational activities. The zoo, like most other traditional places, mostly uses static panels and written materials to teach people about animals and how to protect them. These tools do have a purpose, but they don't really meet the needs of today's consumers, especially younger people who are used to changing online content (Smith & Johnson, 2020). Because of this, many visitors may not learn much, and messages meant to teach may not work after the visit. An augmented reality app for Zoo Johor makes the difference less noticeable. People can interact with and see 3D animals on their phones with the app, which makes the experience more personal and fun. We must respect animals and ensure tourists have fun. In this case, augmented reality combines what people expect from the internet today with traditional zoo exhibits (Garzón et al., 2019). Zoo Johor has been a popular place for families, students, and tourists to go since it opened in 1928. People can learn more about biodiversity and protecting nature by interacting with animals in new ways. But the signs and displays that tell you about things around the zoo don't change frequently. The ways of teaching are based on what works in the real world, but kids and teens today, who are very proficient with technology, might not think they are effective enough (Smith & Johnson, 2020). People who go to these events want them to be fun and interesting. Using augmented reality is one way to try to solve this problem in new and intriguing ways. Zoo visitors can use augmented reality to see and interact with realistic 3D models of animals, learn about how they act, and take pictures with virtual animals. Such an approach makes it easier to learn and makes each visit more fun. Zoo Johor can use augmented reality to meet the needs of its visitors and teach the public at the same time. Research shows that using digital tools like augmented reality the right way can make people more interested and involved and help them learn more in informal settings (Garzón et al., 2019).

1.3 Addressing the Gap in Interactive Wildlife Learning

Although there is a lot to learn in zoos, some places still use educational tools that do not engage the visitor. Here, the wide variety of people travelling to Zoo Johor can be a challenge since the lack of interactive features might make it tough for many guests to learn details about animal habits, the habitats they live in and conservation. For young people who like to learn using their senses, plain signs might not cut it (Akçayır & Akçayır, 2017). This study shows

that the current method of teaching zoo guests with digital tools is not appealing or engaging enough. Augmented Reality is a great solution because it helps connect people with animals and provides interesting lessons. But, for AR to work well, it should be thoughtfully planned and tested. Here, researcher look into using AR at Zoo Johor to modernise the experience and also help people learn more, find greater enjoyment and support conservation in a cool way. Even though zoos are important for spreading conservation knowledge and educating people about animals, some visitors are uninterested because most exhibits use only text. Young visitors at Zoo Johor may not get the chance to be truly involved with what the place has to offer, as there are few features allowing for interaction. If there is no flow, guests may just run from one exhibit to the next without learning important lessons. Differently, systems such as Augmented Reality turn watching into exploring. AR lets people see, touch and interact with content in an engaging way. Yet, Zoo Johor does not currently have any specific AR experience. Because of this, the US is missing out on the opportunity to bring its schools into the present age and more people who are online. It has been proven that AR helps with learning outside the classroom as well as encouraging students to learn more and keep knowledge for longer (Akçayır & Akçayır, 2017). Therefore, the study will discover how AR supports the zoo by enhancing what visitors learn, how happy they are and how engaged they become with the wildlife.

2.0 METHODOLOGY

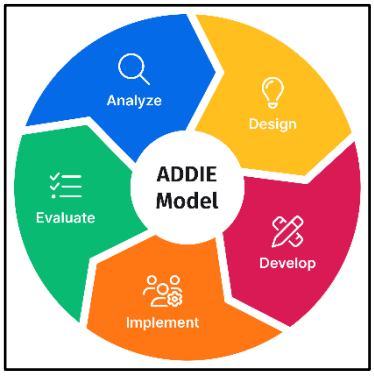

Figure 1: ADDIE Instructional Design Model

The ADDIE instructional design framework was used to make the AR app in this study so that it would meet the needs of users. Because it is clear and useful, the paradigm has been used in education and multimedia development in the past (Branch, 2009). The main steps are analysis, design, development, implementation, and evaluation. The app made it easier to figure out what the zoo needed, as well as how to design, test, and improve it. This design paradigm was used in a quantitative research study that used questionnaires to get structured data. The researcher can focus on making products and making decisions that are good for customers. In the first phase of the study, the researcher watched people at Zoo Johor interact with the exhibits. A lot of people, especially teenagers, didn't pay much attention to static signs and displays. They paid more attention when they were looking at or using their phones. Garzón et al. (2019) found that static teaching technology doesn't always work in places where it shouldn't, like zoos. Study agrees with this. Recent research (Akçayır & Akçayır, 2017) shows that augmented reality (AR) can improve students' learning by giving them more chances to learn in different ways. These suggestions called for a digital tool to make visits to the zoo better. The goal of the design was to make augmented reality apps that were easy to use and

taught something. The first designs and wireframes showed how the app would look and how users would interact with it. The design focused on making it easy for both kids and adults to use. It was very important that the presentation be clear. Animal behaviour, habitat, and ecological importance were all taken into account in each model. Billinghurst and Duenser (2012) found that digital tools must meet usability and instructional goals. This helped us choose what we did. The goal of the design was to combine fun and usefulness. Development made these ideas real. Vuforia and Unity3D are two of the most popular platforms for augmented reality apps on smartphones. They worked together to make the app. The markerless augmented reality method made it so that visitors didn't have to scan printed images. They just pointed their phone at the animals to see them in 3D. The app works with a variety of devices because the 3D objects have few polygons. Viewers could connect with the animals and the text in ways that went beyond just looking at the pictures. According to Yoon et al. (2017), exploring and being curious in interactive 3D environments makes learning better. Zoo Johor was the site of the prototype test. Testers had to install the app by hand on their smartphones because it wasn't yet available on the Play Store. The app lets people at the zoo interact with virtual animals. Most users were able to easily navigate the app, even though it had some problems with usability. Huang et al. (2020) say that testing technology in real-world situations is very important for understanding how it works. This deployment was practical, just like the last one. In the end, client feedback was carefully looked at. A standardised questionnaire was used to rate the software's features, ease of use, educational value, and user satisfaction. Descriptive data made it clear how people responded and how happy they were. The reception was good. People who used the app said it was fun, easy to use, and helped them learn more about animals. Ibáñez et al.'s (2016) recent study shows that augmented reality can help people learn in informal settings. Users suggested adding more species and conservation stories to future versions of the app.

3.0 RESULTS AND DISCUSSION

Figure 2: 3 Stage of AR Apps

Making the AR app required going through the stages of pre-production, production and post-production. All the stages contribute in their own way to ensuring the project is done successfully. Before any work on the project took place, there was research and analysis to start with. We made simple field observations at Zoo Johor both to see the current experience of visitors and to choose the most suitable modern changes. Together with educators, we discussed and established the design and content for the AR application by consulting scholarly research. The wireframe made at this stage helped define the design of the app, who the main user would be and what the project would include. The evaluation of the project by a SWOT analysis revealed that the messaging should be passable and noticeable for kids and their families. Creating the application was the major objective of this stage in the manufacturing process. World Zoo uses Unity3D and Vuforia to develop an app that enables users to see and interact with various animal models in their smartphones without having to scan any markers. Ensuring that all items such as 3D models, were usable on phones, the developers opted to build the game with low-poly techniques. The interface was made straightforward and basic, so users could get around it with no difficulty and few things to choose from. We developed a process where we

kept adding, checking and improving functions due to input from the users. A group of the zoo's guests reviewed and used the prototype in person when developing the main installations. We made use of questionnaires and watched users interact with the app in everyday life during this step. Many reviewers gave positive feedback about the product. At the post-production stage, all data was examined and prepared so it could be discussed in this chapter.

Figure 3: 3 Process AR Development

This chapter shows data collection results and discusses them in connection to study objectives. The usability, effectiveness, and influence of the markerless Augmented Reality (AR) application on visitor experience were assessed using structured questionnaires, semi-structured interviews. This section presents the findings from a user feedback survey on the implementation of Augmented Reality (AR) at Zoo Johor to promote interactive learning experiences. A total of 56 respondents participated, representing various age groups, primarily between 18–25 and 26–35 years old. The gender distribution was balanced, and participants included both those who had prior experience with AR and first-time users. Overall, the results show a highly positive response toward the AR experience. In terms of usability, the application was perceived as user-friendly, with a mean score of 4.43 for ease of use and 4.50 for app functionality. Most users reported smooth interaction with the AR features (mean = 4.39), suggesting that the technical implementation was stable and accessible for users across different backgrounds. Regarding user engagement, the experience was found to be significantly more engaging than traditional static signs, with a high mean score of 4.46. Respondents also rated the experience as enjoyable (mean = 4.45), indicating a strong level of satisfaction. Although the realism and visual appeal of the 3D animals received slightly lower ratings (mean = 4.27), the response was still largely favorable, suggesting that visual presentation could be further enhanced in future iterations. From a learning perspective, the AR experience proved effective. Participants reported better understanding of animal facts (mean = 4.41), learned new information (mean = 4.45), and agreed that the app made learning more fun (mean = 4.41). These findings highlight AR's potential as a tool for informal education, especially in engaging younger audiences through interactive media. The emotional and behavioral impact of the AR

experience was also encouraging. Many users expressed increased interest in wildlife (mean = 4.30) and felt that the experience contributed to greater conservation awareness (mean = 4.41). The majority of respondents (mean = 4.54) indicated they would recommend the AR app to others, reflecting overall satisfaction and approval. Only a small number of participants responded to the open-ended questions. One mentioned that they particularly enjoyed interacting with 3D animals, while very few suggestions for improvement were recorded, indicating general contentment with the experience. In summary, the feedback confirms that the AR implementation at Zoo Johor was well-received, fulfilling its objective to enhance learning and engagement. The findings suggest strong potential for AR to be integrated more widely in educational and recreational environments to support wildlife awareness and conservation efforts.

Table 1: Summary of User Feedback on AR Experience at Zoo Johor

Key Theme	Item	Mean	Median	Mode	Std. Dev.	Interpretation
Usability	User interface was clear and easy to use	4.43	4.5	5	0.63	App is user-friendly and intuitive
	App functioned properly without technical issues	4.50	5.0	5	0.60	App was stable and reliable
	Interaction with AR animals was smooth	4.39	4.0	4	0.56	Mostly smooth interactions with room for slight improvement
Engagement	Felt more engaged compared to reading static signs	4.46	5.0	5	0.63	Higher engagement through AR
	The AR feature was enjoyable to use	4.45	5.0	5	0.63	Strong enjoyment of the AR experience
	3D animals were realistic and visually interesting	4.27	4.0	4	0.70	Good visual quality, with room for enhancement
Learning Outcomes	Helped me understand animal facts better	4.41	4.5	5	0.65	Effective in improving knowledge

	Learned something new about animal behaviour or habitat	4.45	4.0	4	0.57	Delivered new educational content
	Made the learning process more fun	4.41	4.5	5	0.65	Fun and effective learning approach
Emotional/Behavioral	Felt more interested in wildlife after using the AR	4.30	4.0	4	0.57	Moderate increase in interest toward wildlife
	Believe AR can help promote conservation awareness	4.41	4.0	4	0.60	AR supports conservation education
	Would recommend the AR experience to others	4.54	5.0	5	0.54	High willingness to recommend

4.0 CONCLUSION

The findings in this chapter explain how the AR application influenced the experience of visitors at Zoo Johor. Using the ADDIE model and evaluation, the project managed to highlight how Augmented Reality could be effective in engaging people during informal learning experiences. The study revealed that most people found the app simple, entertaining and Efficient at presenting correct facts about animals preferred than with the signs. The feedback showed that people liked how attractive the 3D animals are, how easily they could view the models and how interesting it was to place virtual animals into real surroundings. To sum up, the findings suggested that using AR improves student engagement and learning by matching what today's learners are used to in digital environments. The findings also showed where conservation campaigns could be improved by including more important conservation information and handling the technical obstacles encountered outside. All in all, the AR application in this project met its goals for education and experience and got positive comments from various users. Therefore, these results underline the importance of AR at zoos and encourage more studies and efforts to enhance its impact, offer more interactions and raise awareness for preserving wildlife.

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Development of Interactive Website Design Elements to Enhance Information Access and User Engagement for Galeri Seni dan Pelancongan Pontian

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ABSTRACT

The Galeri Seni dan Pelancongan Pontian in Johor, Malaysia, has faced challenges in reaching broader audiences due to its limited online presence and outdated methods of information dissemination. As digital engagement becomes increasingly essential for promoting cultural spaces, there is a need to develop an accessible and interactive platform to attract and inform visitors more effectively. The main objective of this study is to develop a user-centered interactive website that improves access to exhibition and event information while enhancing user engagement through dynamic and visually appealing digital features. This study employed a combination of website development using Webflow and usability testing. The website incorporated features such as virtual gallery tours, dynamic event calendars, and feedback mechanisms. A total of 51 participants were involved in the evaluation process through surveys and direct observation to assess usability, interactivity, visual design, and overall satisfaction. The finding shows that all constructs related to the website received high mean scores, indicating a strong overall evaluation. Usability scored the highest (4.41), followed by overall satisfaction (4.39), aesthetic design (4.32), and interactive features (4.27). These results reflect a high level of readiness for the website in terms of user experience, design appeal, interactive functionality, and user satisfaction. In conclusion, this study demonstrates that a well-designed, interactive website can serve as an effective tool to enhance information access and user participation in cultural spaces. The findings offer valuable insights for cultural institutions aiming to strengthen their digital engagement.

Keywords: gallery, interactive website, user engagement, usability, virtual tour

1.0 INTRODUCTION

In today's digital world, the cultural sector is starting to realize how crucial digital interaction is for reaching more people and having a bigger impact. Rosli (2023) says that cultural organizations like museums and art galleries need to provide accessible and interactive platforms to encourage people to become involved and promote events and exhibitions effectively, especially since more people are looking for information online. Sylaiou et al. (2010) say that this move towards digital platforms is essential not just for reaching more people but also for giving those who cannot visit physical venues more interesting experiences.

Art and culture are now easier to find and enjoy because of rapid improvements in technology. Rosli (2023) says that old ways of getting information out there, such as printed pamphlets and posters, do not work as well on modern, tech-savvy audiences. Simon (2010) talks about how galleries and museums are using new methods like virtual tours, interactive online events, and social media involvement to stay relevant and sustainable. As Walker (2014) points out, it is now essential for cultural institutions to create a digital platform that puts the user first and delivers information while encouraging meaningful interaction and connection with artworks.

This study is focused on creating a dynamic, user-centered interactive website for Galeri Seni dan Pelancongan Pontian to improve visitor access to exhibition and event information through engaging and interactive elements. This is because digital engagement is becoming more and more critical for marketing cultural spaces.

1.1 Art Gallery in General

Art galleries are cultural organizations that show and protect works of art. They give artists a place to show their work and viewers a way to experience a wide range of artistic styles, as Qin, Z. (2022) points out. Fernández, Goss, and Marshall (2022) say that these places encourage creativity, critical thinking, and cultural interchange. They have a wide range of mediums, from classic painting and sculpture to modern digital and interactive art. According to Sicilia (2021), visitors to galleries do not just look at the art; they also think about it and feel it. They learn about it and reflect on it. As technology becomes more common, many galleries increasingly use digital tools to get visitors more involved. Rosli (2023) says that virtual galleries, internet shows, and interactive displays are new methods to enjoy art that go beyond what you can see in person. Wang (2022) talks about how the rise of digital art has made it possible for galleries to show more multimedia works. This makes online involvement a vital way to keep cultural impact alive. Falk and Dierking (2016) also say that galleries are educational resources since they typically organize workshops and community programs that may be expanded through digital platforms to enhance inclusivity and spread information more widely.

1.2 Galeri Seni dan Pelancongan Pontian

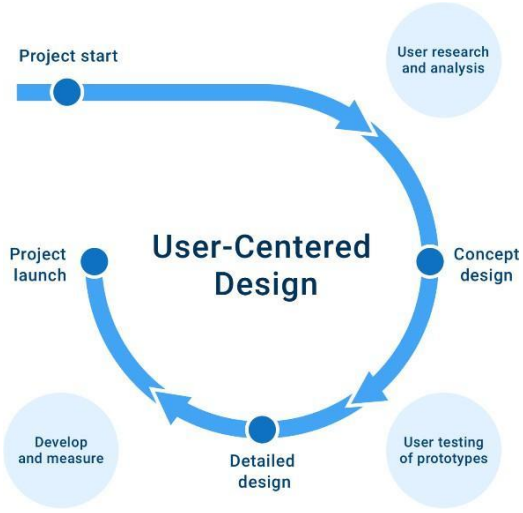
The Galeri Seni dan Pelancongan Pontian is an essential cultural center in the Pontian district of Johor, Malaysia. It shows off the area's rich creative history and stories from the past. Johor State Tourism (2022) says that the gallery shows off the work of local artists and helps tourism by promoting Pontian's cultural character. However, this gallery has trouble getting a wide range of people to come, much like many other cultural institutions. Traditional ways of spreading information, such as using pamphlets, posters, and events that people may attend in person, do not reach as many people, especially younger, tech-savvy visitors and people from other countries. Salleh and Hassan (2020) say that these old-fashioned ways do not satisfy the needs of today's viewers. Also, the gallery's weak web presence makes it harder for people to get involved. Rahman (2020) talks about how important it is for cultural institutions to have a strong digital presence, and this makes it harder for them to be seen on global platforms. As the world becomes more digital, it is essential to create an interactive online presence that promotes the gallery's offers and encourages visitors to interact with one another in meaningful ways. The goal of this project is to improve Galeri Seni dan Pelancongan Pontian's digital engagement by creating an interactive website that gives users full access to exhibitions, events, and services. This platform will help the gallery reach more people and give visitors from all over the world and from the area a chance to have immersive experiences.

1.3 Challenges of the absence of a digital platform

Despite its cultural significance, Galeri Seni dan Pelancongan Pontian now lacks a comprehensive digital presence, limiting its ability to communicate successfully with today's technologically savvy consumers. According to Salleh and Hassan (2019), the gallery's reliance on traditional physical dissemination techniques limits its capacity to attract a broader and more diverse visitor base, including those who live far away or prefer digital connections. Rahman (2020) says that the lack of a user-friendly, interactive web platform makes it much harder for visitors to get involved with exhibitions and events. There is a growing need for a digital platform that is easy to use and dynamic and that not only provides detailed information but also fun, interactive experiences. This lack of digital presence makes it harder for the gallery to

get more visitors and get people involved in the community. This study suggests that Galeri Seni dan Pelancongan Pontian should build an interactive website to deal with these problems. It is meant to connect the gallery with its audience by making the experience better for visitors and reaching more people. As Rosli (2023) proposes, this digital project will better promote exhibitions and events, thereby boosting the gallery's cultural presence in the digital realm.

2.0 METHODOLOGY



Source: International Organization for Standardization (2010)

According to Norman (2013), this project's guiding methodology is the User-centred Design (UCD) framework, which is used to develop an interactive platform for Galeri Seni dan Pelancongan Pontian. UCD is a design method that puts the user first at every step of production. This makes sure that the finished product meets the user's needs, wants, and habits to provide them with the most outstanding experience possible. The first thing to do is to do much research about the target audience. Gulliksen et al. (2023) say that interviews, questionnaires, and observations can be used to find out what consumers desire, what issues they have, and what their aims are. It is also vital to establish user personas at this time. User personas are made-up profiles that stand for essential user groups and assist in making the design meet real needs (Cooper, Reimann & Cronin, 2007).

After doing user research, the problem is obvious, and design goals are set. According to Preece, Rogers, and Sharp (2015), the problem with Galeri Seni dan Pelancongan Pontian is that the gallery does not have much of an online presence and is not very interactive, which makes it hard for people to get involved and find out about exhibitions. The research outlines design goals that are all about making a website that is easy to use, interesting, and provides information quickly and efficiently while also getting more people to visit. User stories are developed to highlight what most users want, such as looking at current exhibitions or checking event schedules (Rubin & Chisnell, 2008). The following step is the ideation phase, which is when design concepts and solutions are made. This includes coming up with crucial features like interactive event calendars, virtual tours, and multimedia content to make the user experience better (Sharp, Rogers & Preece, 2019). At this point, wireframes and prototypes are made to indicate how the site will be set up and how users will use it. This makes it easier to receive input and make changes early on. Maguire (2001) says that working together as a team of people from different fields makes sure that the design is possible and fits user needs.

Next, the process stresses iterative design and prototyping, which means that prototypes are evaluated with real users to see how easy they are to use and how well they work, as ISO 9241-210 (2010) suggests. Usability testing sessions find problems with navigation and things that make it hard to finish tasks. Then, the design is updated through several rounds of testing to make it easier to use and more interesting, which is also what Nielsen (1994) said. Bevan (2009) says that the cycle of creating, testing, and refining is necessary to make the end product more straightforward to use. Once a functional prototype is made, the project moves on to the next step. Developers ensure that the design and interactive parts of the website are correct before it goes live. Faulkner (2003) states that quality assurance testing makes sure that everything works on all devices and browsers and fixes any problems before the product is made available to the public. Finally, after the website goes live, it is constantly checked. Kujala (2003) says that ongoing user input and analytics data on engagement and satisfaction help make the platform better, making sure it stays helpful and relevant over time. This continuing cycle of evaluation makes sure that Galeri Seni dan Pelancongan Pontian stays connected with its online audience by keeping up with changing user needs and new technology.

This research used a face-to-face survey to gather data from 51 participants aged 18 and older, utilizing a quantitative methodology with a convenience sampling approach (Etikan, Musa & Alkassim, 2016). Participants were chosen based on their availability and willingness to participate, potentially introducing biases due to non-random selection. The survey consisted of multiple sections: demographic information (age, gender, interest in art) usability (ease of navigation), aesthetic design (visual appeal), interactive elements , and overall satisfaction (general feedback on the user experience). This methodology was created to collect data relevant to the research aims, emphasizing critical elements of website functionality. The gathered responses were examined utilizing the Statistical Package for the Social Sciences (SPSS), employing descriptive statistical analysis to assess mean scores and percentage distributions. The study delivers insights into participants' perceptions, addressing the research questions and evaluating the website's effectiveness.

3.0 RESULTS AND DISCUSSION

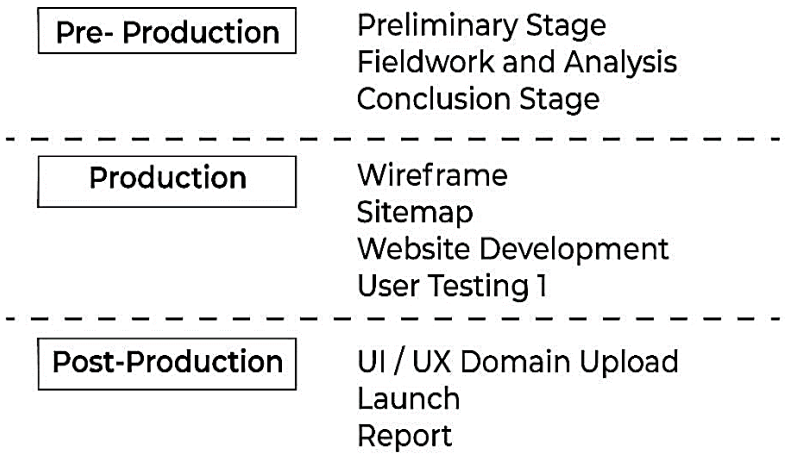


Figure 1: Framework of stages

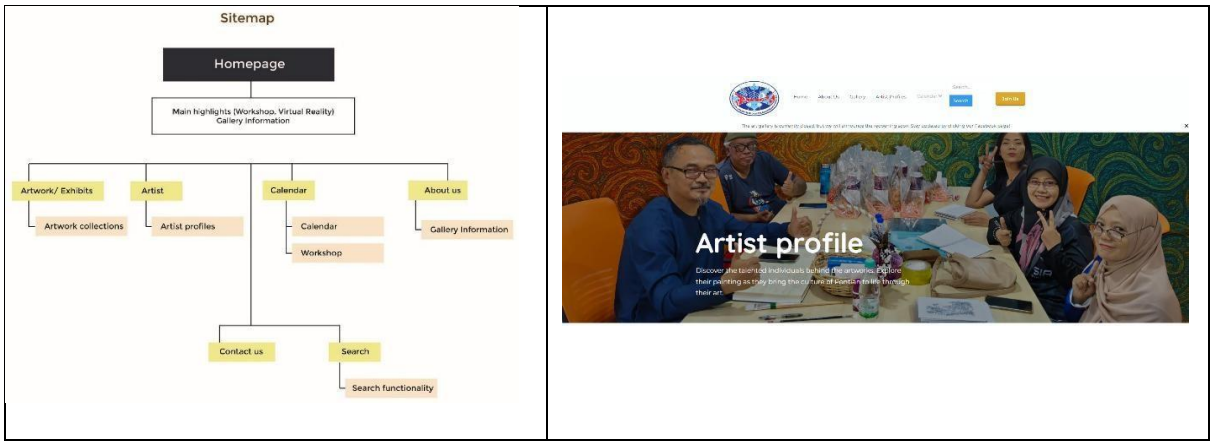
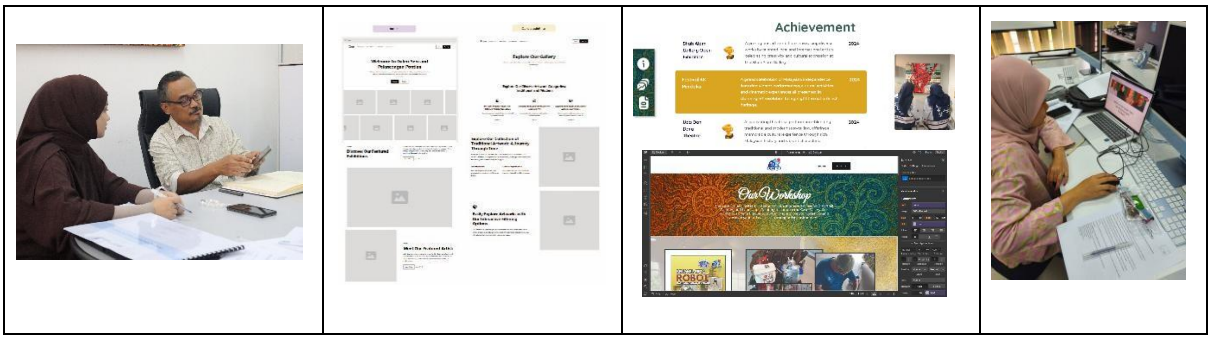


Figure 2: Sitemap and layout of interactive website

The pre-production phase established the fundamental foundation for the project. Preliminary research, fieldwork, and data analysis were conducted to understand project requirements and user needs comprehensively. This phase established a robust foundation by defining project objectives and scope, thereby reducing potential risks in subsequent stages. The conclusion phase of pre-production entailed synthesizing research findings to inform the design and development processes effectively.



a. user research and analysis | b. concept design | c. developing | d. user testing

Figure 3: UCD process

The project progressed from the planning phase to execution during production. The wireframe and sitemap were developed to visually represent the website structure, facilitating user-friendly navigation and a coherent content flow (Figure 3). The following phase involved website development, during which coding and design implementation occurred. User Testing 1 constituted a vital component of this phase, facilitating early feedback from target users. This testing identified usability issues, design flaws, and technical bugs, facilitating iterative improvements to enhance user experience and functionality prior to final deployment. The post-production phase concentrated on the finalization and launch of the project. The UI/UX design was refined, and the domain was deployed to ensure the website's online accessibility. The official launch signified the project's shift from development to live operation. A comprehensive report was prepared to document the project's journey, outcomes, and reflections. This phase confirmed that the project achieved its objectives and established a foundation for subsequent enhancements or extensions.

The website's sitemap, illustrated in the figure, demonstrates a structured and intuitive layout that improves user navigation and accessibility. The homepage serves as the central hub,

prominently displaying key highlights such as workshops and virtual reality experiences, along with essential gallery information, thereby facilitating immediate engagement with current and interactive content for visitors. The content is systematically organized into essential sections: Artwork/Exhibits, Artist Profiles, Calendar Events, About Us, Contact Us, and Search Functionality.

This organization facilitates user exploration of artwork collections, provides information on featured artists, keeps users informed about upcoming events, and enables efficient retrieval of specific information through the search function. The sitemap demonstrates a user-centered design approach by minimizing the depth of navigation menus, which decreases user effort and cognitive load. The incorporation of interactive elements, including workshops and virtual reality, reflects a contemporary and immersive approach that has the potential to engage and maintain visitor interest. The sitemap's hierarchical and clear design facilitates effective content delivery, enhances engagement, and positively impacts the overall user experience on the website. The results were derived from questionnaire responses provided by 51 participants, indicating diverse assessments of essential website characteristics. The website's interactive component achieved the highest mean score of 5.25, exhibiting low variability, which suggests solid positive feedback. The aesthetic appeal received a mean rating of 4.41, whereas usability achieved a mean score of 4.37, indicating generally favorable yet somewhat varied responses. The overall satisfaction shows a moderate mean score of 3.29, indicating a range of opinions among respondents.

According to the mean score interpretation scale established by Riduwan (2012), the constructs of usability, overall satisfaction, aesthetic design, and interactive features exhibited high levels of readiness and user acceptance. Usability achieved the highest score (mean = 4.41), followed by overall satisfaction (mean = 4.39), aesthetic design (mean = 4.32), and interactive features (mean = 4.27). The findings demonstrate a positive reception of the website's design, functionality, and user experience.

Table 1: Mean and interpretation mean score (Riduwan, 2012)

Mean Score	Interpretation of Mean Score
1.00- 2.33	Low
2.34- 3.67	Moderate
3.68- 5.00	High

Table 2: Demography

Items	Frequency (N=51)	Percent (100%)
Age		
18-25	33	64.7
26-35	14	27.5
36-45	4	7.8
46-55	-	-
56 and above	-	-
Total	51	100

Gender		
Male	21	41.2
Female	29	56.9
Total	51	100
Interest in art		
Very high	17	33.3
High	18	35.3
Moderate	16	31.4
Low	-	-
Very Low	-	-
Total	51	100

The data collected from 51 respondents provides essential demographic information, specifically regarding age and gender. A significant percentage of respondents (64.7%) fell within the 18-25 age, while a smaller number (27.5%) belonged to the 26-35 age group. Participants from older age groups were notably scarce, with no respondents in the 46-55 or 56 and above categories. The sample consisted primarily of females, accounting for 56.9% of participants, whereas males represented 41.2%. The majority of respondents demonstrated a favorable interest in art, with 33.3% reporting very high interest and 35.3% indicating high interest. A minority of respondents (31.4%) showed a moderate level of interest, while none indicated a low or very low interest in art. The data reveals a high level of engagement with art among participants, particularly within the younger age group.

Table 3: UX Evaluation

Item	Mean	Interpretation
Usability		
Navigating the website is straightforward.	4.47	High
The menus and categories are logically organized.	4.49	High
Finding information is easy.	4.33	High
The website's search functionality is helpful.	4.39	High
The website operates smoothly without technical glitches.	4.39	High
Aesthetic design		
The website's design is visually appealing.	4.41	High
The color scheme aligns with the overall design.	4.25	High
The fonts are well-suited for users.	4.29	High
The text sizes are readable.	4.37	High
The text alignment is consistent.	4.20	High
The visuals are well-aligned with the overall design.	4.37	High
Interactive Features		
The navigation menu is easy to use.	4.25	High
The buttons are easy to click and responsive.	4.27	High
The interactive forms are functional.	4.24	High
The menus are organized.	4.25	High
The VR features are fun and easy to use.	4.24	High
The VR tour makes me want to visit the Galeri Seni dan Pelancongan Pontian in person.	4.37	High

The VR experience helps me understand and enjoy Pontian's art and culture.	4.22	High
The interactive features encourage me to explore more of the Pontian attractions.	4.31	High
Overall satisfaction		
I am satisfied with my experience using the website.	4.33	High
The website meets my expectations for an art and tourism platform.	4.37	High
I would recommend this website to others interested in Pontian's culture.	4.33	High
I am likely to revisit the website to explore more of Galeri Seni dan Pelancongan Pontian.	4.29	High
The website captures the essence of Pontian's culture and makes me want to visit the gallery in person.	4.33	High
The website makes me excited to visit Pontian's art gallery after browsing online.	4.53	High
The content on the website motivates me to experience Pontian's art and culture in person	4.53	High

The table provides an evaluation of a website based on criteria including usability, aesthetic design, interactive features, and overall satisfaction, determined by a Likert-scale questionnaire. The respondents evaluated their experiences on various items, revealing elevated levels of satisfaction. Usability assessments indicated that factors such as straightforward navigation and easy access to information received high ratings, with a mean score of 4.47 for the statement "Navigating the website is straightforward." Aesthetic design elements, including the color scheme and font readability, achieved a high average score of 4.41. The interactive features, such as user-friendly menus, functional forms, and virtual reality (VR) experiences, received favorable evaluations, achieving a mean usability score of 4.25 for the VR components. Respondents indicated high overall satisfaction, reflected in a score of 4.35 for the statement, "I would recommend this website to others."

In conclusion, the website effectively meets user expectations in several areas. The positive feedback regarding usability, design, and interactive features suggests that the website is user-friendly and visually appealing, thereby enhancing the overall user experience. The elevated ratings for VR features and the exploration of additional attractions indicate the website's effectiveness in providing engaging and informative content concerning Pontian's art and culture. The findings indicate that the website may serve as an effective platform for the promotion of tourism and cultural exploration, with prospects for ongoing utilization and endorsement by users.

Table 4: Mean and level scores of each construct

Construct	Mean	Level
Usability	4.41	High
Aesthetic Design	4.32	High
Interactive Features	4.27	High
Overall Satisfaction	4.39	High

4.0 CONCLUSION

This study demonstrates the effectiveness of developing an interactive website to improve user engagement and information accessibility for Galeri Seni dan Pelancongan Pontian. The implementation of User-centered Design (UCD) enables the website to successfully incorporate interactive features, aesthetic design, and user-friendly navigation, resulting in high ratings from participants. The website demonstrates strong usability, high satisfaction scores, and favorable feedback regarding interactive features such as virtual reality tours and event calendars, indicating that it fulfills the expectations of its target audience. The platform's usability scores average 4.41, with visual appeal rated at 4.32 and interactive features averaging 4.27, indicating a strong potential for enhancing engagement with the gallery's cultural offerings.

The findings show that the website serves as an effective instrument for promoting the gallery's exhibitions and improves the overall visitor experience by providing dynamic and immersive digital content. The feedback from users across various age groups, particularly from younger audiences, highlights the necessity of modernizing cultural spaces to maintain relevance in a digital age. This study demonstrates that an effectively designed, interactive website is essential for promoting cultural institutions, enhancing their outreach, and boosting user engagement, which is crucial for the gallery's sustained growth and success in the digital era.

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Development of Narrative Animation of Johor's Batik Motif The Batik House by Imarazak

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ABSTRACT

This research aims the development of a narrative animation aimed at promoting Batik Johor, a culturally significant textile tradition from Malaysia, in collaboration with The Batik House by Imarazak. Despite Batik Johor's historical and artistic value, it remains underappreciated globally due to ineffective promotional methods that fail to engage diverse audiences, particularly younger generations. Current platforms such as social media improve visibility but lack the narrative depth to fully convey the Batik making process and its cultural significance. The research's primary objective is to identify suitable content for a narrative animation that is both educational and entertaining and to develop a 2D animation that highlights Batik Johor's artistic and economic value while promoting The Batik House as a community learning space. This study conducted a qualitative research approach, utilizing a comprehensive literature review alongside in-depth interviews with the owner of The Batik House by Imarazak to gather detailed insights on the cultural significance and production process of Batik Johor. Results shows that the animation effectively increased awareness and appreciation of Batik Johor's uniqueness, resonating well with young viewers and wider audiences. It conveyed the complexity of Batik production and encouraged cultural pride and community involvement. However, limitations included the lack of interactive features and the inability of 2D media to fully represent the tactile nature of Batik making. In conclusion, 2D narrative animation is a powerful tool for cultural promotion. Future projects should incorporate interactivity, explore other regional Batik traditions, and expand the storytelling approach for broader cultural impact.

Keywords: batik johor, 2D animation, cultural heritage, narrative animation, the batik house.

1.0 INTRODUCTION

Cultural heritage is now shared and saved differently around the world because of the development of digital media. Narrative animation has become especially attractive among digital tools because it blends visual storytelling and lessons on traditional arts. This style of animation makes use of 2D visuals plus narrative elements like story characters, background sounds and movement to help explain complex stories to many people (Ng & Ali, 2021). Among Malaysians, Batik Johor is regarded highly for its precise designs and ancient wax resist coloring, both essential in showing regional character (Tan & Lim, 2021). Because there have not been enough efforts to promote it globally, Batik Johor is not very well known outside of Malaysia.

At The Batik House by Imarazak in Kompleks Kraf Johor, the focus is on saving and propagating Batik Johor through classes, shows and community events. Yet, although these actions help locally, getting the word out to people worldwide requires trying new digital strategies. Using 2D narrative animation, the research aims to unite old traditions with modern

digital methods, offering education, enjoyment and information about the artistic, cultural and economic value of Batik Johor. It presents the research in the context of larger cultural promotion debates and gives the reasons for relying on animation as a key way to spread awareness and appreciation.

1.1 Narrative Animation

This type of animation is called narrative because it weaves together graphics, movement, audio and text to express information in a sequence (Gordillo, 2019). When used in schools and cultural settings, 2D animation is efficient in breaking down culture topics and attracting interest from viewers both mentally and emotionally (McCloud, 2020). Things like the way a video is shot, its narrative structure, the timing of moves and the use of sound are some of its main features, helping learners get involved. Using narrative animated productions makes it easier to communicate cultural assets like traditions and crafts which can be very hard to communicate with non-animated images (Rauscher & Hiebert, 2019). With these strategies, Batik Johor can be explored more easily by people of different ages and cultures, though generally not part of traditional cultural education (Tan & Lim, 2021).

1.2 The Batik House by Imarazak

Batik House by Imarazak has had a crucial role in the Johor region by looking after and promoting Batik Johor. It acts as a studio, shop and learning center, letting visitors try out traditional Batik methods and learn about them (Ismail & Kamaruddin, 2018). Much of what it does helps keep the craft important in the face of modern trends. According to earlier studies such institutions help defend culture by focusing on true values while also following new trends in modern promotion (Hassan & Lee, 2020). The project takes this further by combining digital storytelling, especially with narrative animation which opens up more opportunities for sharing The Batik House's mission with people worldwide. The field of digital cultural promotion points out that mixing tradition with modern media techniques encourages people to involve themselves more and appreciate heritage more thoroughly (Ng & Ali, 2021; Sullivan & Korman, 2020).

1.3 Problem and Challenges

Batik Johor has a strong background in culture and history, but its global fame is limited by various problems. Even though Batik Johor has special cultural and craft value, mainly photos and videos shared on Instagram and Facebook are now used to promote it (Tan & Lim, 2021). Generally such programs reveal the results of production, but they do not go into much detail about the processes or offer enough context for younger people who prefer educational storytelling (Yusof, 2022). Another point is that the physical involvement in Batik creation which is fundamental to the craft, is hard to present in pictures alone and lessens the experience for viewers. Also, the present methods of promotion do not give enough information about Batik Johor and its role in the local economy which reduces how much the promotion resonates with the audience. Another important matter is missing animated content which could combine storytelling, education and visuals in a way that better shows Batik heritage. This situation points out that innovative digital tools, especially 2D narrative animation, can help promote culture by exhibiting production steps and important meanings, so that more people from different groups can fully understand and value the culture, because Batik is made by hand, it is hard for websites or social media to show its textures or other senses, this means that strictly digital content is less effective for this craft. This situation means that it is important to find innovative ways to tell stories, teach people and entertain them about Batik Johor through 2D narrative animation (Ng & Ali, 2021).

2.0 METHODOLOGY

A quantitative approach was used to check how the 2D narrative animation helped promote Batik Johor. The main way data was collected was through an online questionnaire built to collect feedback on how users found the animation, its educational impact, appearance and whether they were satisfied. Choosing the quantitative approach made it possible to see how well Batik Johor's heritage was shared by the animation, as well as how much the audience was involved. The survey was sent out to 50 people who had seen the animation. People were invited to take part if they knew about Batik Johor and used digital media often. The survey included questions used in Likert scale format (from "Strongly Agree" to "Strongly Disagree") to understand how respondents felt about certain parts of the animation, for example, how simple or straightforward the animation was, how useful it was and how well it caught their attention. The questionnaire included aspects that allowed examining the animation's explanation of Batik-making, its cultural meaning and its beauty.
To gather data, the following steps needed to be performed.

i. **Preliminary Data Collection:** A review of literature help to understand earlier studies on narrative animation in the field of cultural heritage promotion which guided the development of survey questions.

ii. **Questionnaires:** Individuals who had taken part in cultural activities or were members of digital media platforms were targeted by email and on social media and the questionnaire was delivered to them.

iii. **Data Analysis:** The gathered information was looked at using statistics software to get details about the data. Each answer given on a Likert scale was used to calculate frequencies, percentages and the mean score to better understand what the study participants thought. After that, the data was analyzed to find out how well the usability, educational aspect and overall design worked in the narrative animation. Looking at theresults in this way made it easy to find general trends, show what worked well and also learn which parts could use some improvement.

The study wanted to analyze how well the animation presented cultural and educational themes to the widest possible audience by relying on quantitative methods. Thanks to statistical analysis, these key areas where the animation stood out and needed further fixes could be spotted.

3.0 RESULT AND DISCUSSION

The table below highlights a range of studies that supported the research on how narrative animation helps to promote cultural heritage. From these studies, we learn how digital storytelling engages people and highlights the importance of Batik Johor in the community.

Table 3.1 Range Of Studies

Author(s)	Title	Narrative Animation in Promotion
Tan & Lim (2021)	*The Forgotten Art: A Study of Batik Johor and Its Cultural Significance in Modern Malaysia*	Underlines how Batik Johor is not as often featured as it should be in promotion and suggests that animation would be a better way to highlight its rich culture.
Gordillo (2019)	*The Art of Storytelling Through Animation*	Gives examples of how animation, especially in stories, helps people engage more with culture and supports learning through stories.
McCloud (2020)	*Understanding Comics: The Invisible Art*	Examines if visual narratives are effective for capturing viewers' attention, especially when discussing how animation can help promote culture.
Rauscher & Hiebert (2019)	*Educational Impact of Interactive Digital Media in Learning Environments*	Outlines how interactive digital media such as animation, can help people understand complicated aspects of culture which is important for promoting cultural heritage.
Ng & Ali (2021)	*Digitalizing Cultural Heritage: Engaging the Younger Generation Through Interactive Storytelling*	Marks out animation and similar forms of digital media as essential for involving the youth in saving culture.
Yusof (2022)	*Preserving Batik in the Digital Age: Challenges and Opportunities in Promoting Local Crafts*	Explores how animation can play a key part in modern times to support traditionally made Batik.

Result presents the outcomes of the study, focusing on the different stages of the animation process: pre-production, production and post-production and gives an analysis of the feedback gathered with the Google Survey. From the data, we learn how well animation helps to spread awareness about Batik Johor's cultural background, its educational impact and its level of user interest. A questionnaire was used to collect data from people who had watched the 2D narrative animation. It was made to collect numbers and words on how easy the platform is to use, how understandable the content is, how attractive the layout looks and how satisfied respondents are. The survey had 50 total participants. How the sample is made up in terms of demographic characteristics is described in the pie chart below

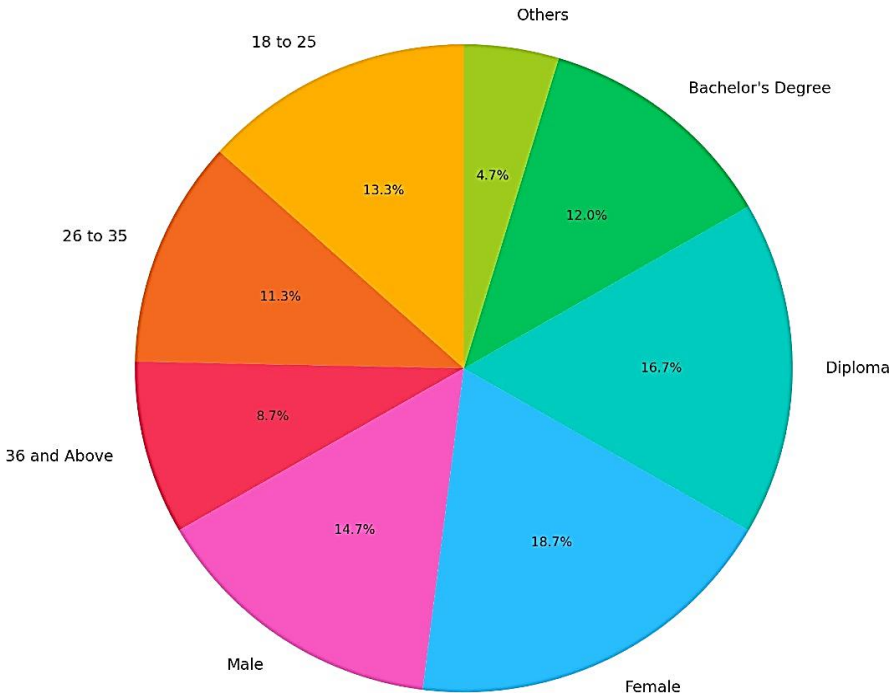

Figure 3.1: Pie Chart of Demographic Distribution of Respondents

Studies indicate that most respondents are young adults and slightly more are woman. Many participants are educated to at least diploma level and this is adequate for studying how digital narrative animations support learning.

3.1 Pre-Production Phase

Study materials and answers from the interviews influenced the way the animation was drawn up and developed. Batik Johor focused on its history, the exclusive motifs made in the area and gave a clear visual guide to making Batik. Every part of the story and its order was worked out using storyboarding. The SWOT analysis pointed out that the project's main advantage was its fresh and authentic look which was meant to attract a large number of viewers. Lack of tactile detail due to 2D animation was pinpointed as a weakness. Social media allowed expanding to a worldwide audience, but there was also a challenge from overreaching digital content.

3.2 Production Phase

While making the animation, the artwork for the characters, settings and props was created using Batik Johor as a reference. By using Adobe Animate, the studio made animation to fit the synchronization of speech and sound. Production teams wanted to keep their audience engaged by mixing information with fun, but also keep being true to traditional practices.

3.3 Post-Production Phase

At that stage, editing, blending the images, color correction and mixing the sounds were the main tasks to achieve a clear final product. They paid attention to audio visual synchronization and the picture being clear. The finished animation was sent out to be shared on digital platforms.

3.4 Feedback Analysis

This section features tables that show the analysis of a survey done with 50 participants. The questionnaire concentrated on the 2D animated story about Batik Johor, addressing interaction and usability, the content's influence and overall appearance in Sections B, C and D. The researchers scored the answers using a Likert scale and calculated means to assess the respondents' opinions on how clear, educational and attractive the animation was.

Table 3.2: Usability and Interaction

Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)	Mean Score	Interpretation
The Animation Is Easy To Understand	46.0	40.0	10.0	4.0	0.0	4.28	Strongly Agree
The voiceover was clear and easy to understand.	42.0	44.0	8.0	6.0	0.0	4.22	Strongly Agree
Narrative Animation Enhance Experience	38.0	36.0	20.0	6.0	0.0	4.06	Agree

Table 3.3: Content and Educational Impact

Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)	Mean Score	Interpretation
The Animation Effectively Explains Batik Johor's Heritage And Process	50.0	38.0	8.0	4.0	0.0	4.34	Strongly Agree
I Learned New Facts About Batik Johor	44.0	38.0	12.0	6.0	0.0	4.2	Agree
The Animation Increased My Interest In Batik Johor	40.0	36.0	14. 02	10.0	0.0	4.06	Agree

Table 3.4: Visual Design

Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)	Mean Score	Interpretation
The Visual Design Is Attractive	56. 01	36.0	6.0	2.0	0.0	4.46	Strongly Agree
Use Of Batik Motifs Enhances Cultural Representation	52.0	6.0	12.0	2.0	0.0	4.42	Strongly Agree

Sections B, C and D demonstrate that respondents have positively received the 2D animation promoting Batik Johor. The animation helps explain things clearly and improves the experience of watching, as participants had a strong agreement on its usability. The animation adequately discusses Batik Johor's background, leading many to show more interest in the field. The animation's design appeals a lot to viewers and the use of Batik motifs helps tell the rich culture of Johor through Batik Japanese. To sum up, the study reveals that the animation is effective in how it is used, what it includes and the way it represents cultures, thereby making it useful in promoting Batik Johor's cultural heritage.

3.0 CONCLUSION

It proved that 2D animation is a powerful and successful means to share Batik Johor's cultural heritage. The animation, thanks to its captivating pictures and thoughtfully laid out plot, allowed many in Malaysia to better understand and respect Batik Johor. With animation, the organization managed to introduce heritage craft skills to many new people, mainly young people who might not get involved with such activities normally.

Although the study achieved promising results, it also points out that, due to the medium, frameworks could not fully express the interactive, hands-on process of making Batik. Yet, the excellent results from the study back up the view that 2D narrative animation continues to be a helpful teaching resource that brings aging and culture differences together. By using innovation and cultural traditions together, Batik Johor can ensure they stay important and valued in today's culture for many years ahead.

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Development Of Piaigrove Apps At Taman Negara Tanjung Piai

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ABSTRACT

This study has fully developed and evaluated Piaigrove which is a new mobile app created to benefit the overall experience of visitors to Tanjung Piai in Pontian, Johor. Considering that various user groups may face issues accessing the site, the developers have introduced various functions such as voice-guided tours, audio explanations, up-to-date environmental updates and access without internet. These additions want to help the park become inclusive and interesting for everyone who visits. Developers rely on a mix of strategies and the Spiral Model to keep updating and improving the application so that it is both useful to people and meets coding standards. Optimization of user engagement, comprehension and accessibility is reached in theories by applying cognitive load theory and multimedia learning. It uses videos and images that are blended with geo data for Tanjung Piai, Pontian, Johor, so users can explore the area through easy interaction. By following this system, the educational benefits of the site are raised and visitors end up being more environmentally aware and committed to sustainable travel. Information about usability, accessibility and experience was collected by surveys, interviews and focus groups which pushed for continuous improvements. It is indicated by these findings that Piaigrove addresses accessibility issues, increases the involvement of visitors and promotes eco-tourism development. This project supports the idea that technology can play an important role in both making ecotourism smarter and encouraging access for people with disabilities on tours.

Keywords: accessible mobile application, ecotourism, environmental awareness, sustainable tourism.

1.0 INTRODUCTION

Because of its position at the end of Asia's mainland landmass, Tanjung Piai, Pontian, Johor, is environmentally significant. The whole world acknowledges this area for its impressive biodiversity and lovely mangrove zone. It became a Ramsar site since it is an essential wetland holding a wide range of plants and animals that preserve its environment (Ramsar Convention Secretariat, 2003). These trees assist in sheltering various wildlife, protecting the shoreline and capturing large amounts of carbon which is good for the environment (Johor National Parks, n.d.).

Tanjung Piai draws many eco-tourists because it offers a rare opportunity to explore and enjoy the area's special ecology (Darcy et al., 2010). Still, important though the park is, getting to and moving around it is very difficult for many visitors. Typical signage and printed brochures are usually not enough to experience all that an attraction has to offer. These ways of looking at art may not suit those with disabilities very well, stopping them from fully enjoying everything the site has to offer (Shalini Sanmargaraja & Seow, 2018).

Because of these issues, a mobile app called Piaigrove is being suggested to help visitors and improve the experience. By making use of advanced technology, Piaigrove is able to supply

tourists with a fun and welcoming guide. It offers audio narration that explains places of interest while users focus on the audio rather than the display (Behrendt, 2012; Pundlik et al., 2023). As a result, it makes finding your way in the park a simple process. With this strategy, Piaigrove wants to increase user involvement, spread environmental information and encourage environmentally friendly and open ecotourism in Taman Negara Tanjung Piai (Bartie et al., 2018; Leorke, 2014; Ziyadin et al., 2019).

2.0 METHODOLOGY

2.1 Research Method

Various methods such as interviewing and using statistics are used to guarantee that the study includes all necessary information about the project. In this way, people's opinions are learned through qualitative methods and quantitative information provides insight into how well the product performs (Darcy et al., 2010; Pundlik et al., 2023). The process of developing products takes into account the needs and goals of the target users at every point. As a result, the final product, Piaigrove, is easy to operate, looks professional and helps visitors at Taman Negara Tanjung Piai with any challenges they may have (Shalini Sanmargaraja & Seow, 2018; Seow & Sanmargaraja, 2015).

All of the company's projects are managed using the Spiral Model which proves best for handling big, complicated and transforming projects. The purpose was to use this model as it is adaptable, follows a sequence, detects risks early and regularly uses user feedback (Ziyadin et al., 2019). For each stage in Piaigrove's model, there were four main phases that were worked on and improved as the product grew.

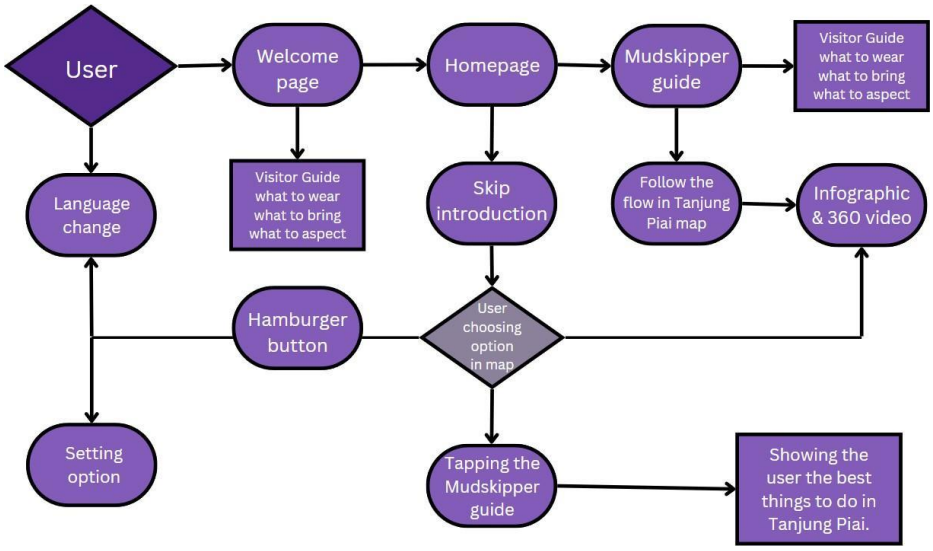

Figure 2.1: User flow for Piaigrove Apps

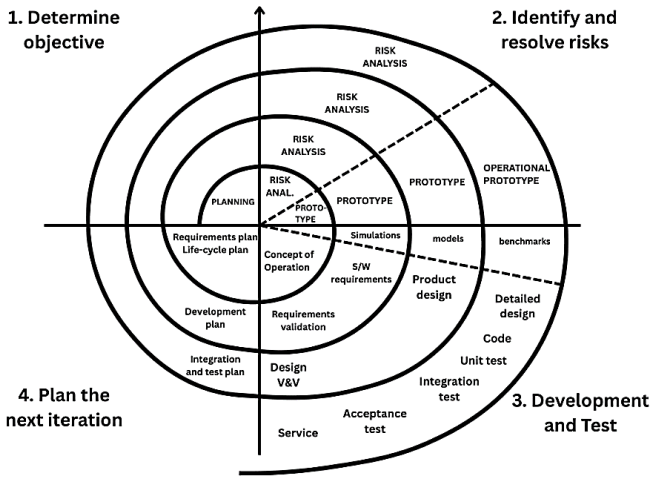

Figure 2.2: Spiral Model

Thanks to the Spiral Model, whatever was discovered through evaluation could be used right away in both current and planned stages of development. By going through this process several times, risks could be handled and the project maintained its high quality and raised user satisfaction throughout (Ziyadin et al., 2019).

2.2 Population and Research Sample

I consider anyone who wants to plan a visit to Taman Negara Tanjung Piai. It was decided to use convenient sampling to get the data required for the quantitative part. In the study, results from 62 users showed how effective and easy it was to use the Piaigrove mobile app. Since the sample was combined from people of different gender, age, race, level of education and job titles, it provided a mix of important experiences in inclusive tourism (Darcy et al., 2010; Seow & Sanmargaraja, 2015).

2.3 Research Instrument

Taking into account the situation, the researchers selected questionnaires as the main tool to collect data for this study. We made the questionnaire to find out about visitors' thoughts and experiences when using the Piaigrove mobile application for Taman Negara Johor Tanjung Piai.

Many of the questions in the questionnaire were designed as multiple-choice to cover demographics, general impressions and the way the Piaigrove app functions. Thanks to this method, data was collected in a well-arranged and organized way from the participants (Darcy et al., 2010; Seow & Sanmargaraja, 2015).

2.4 Data Collection

Without hesitation, the researchers decided to collect data for this study by using questionnaires. The aim of the questionnaire was to get the opinions and experiences of visitors about the Piaigrove application at Taman Negara Johor Tanjung Piai. To collect information, the survey consisted of multiple-choice questions about topics such as people's details, general opinions and the way the Piaigrove app functions. Using this approach made it possible to ask questions in an ordered and clear way to the participants (Darcy et al., 2010; Seow & Sanmargaraja, 2015).

2.5 Data Analysis

To collect the data, the researchers voluntarily decided to use questionnaires in this study.The purpose of the questionnaire was to get visitors' views and experiences regarding the Piaigrove mobile application used at Taman Negara Johor Tanjung Piai. Many of the survey questions were designed as choices to find out about participants' age, experiences and their thoughts on Piaigrove. Thanks to this technique, information from the participants could be gathered using a standard and well-organized process. (Darcy et al., 2010; Seow & Sanmargaraja, 2015).

3.0 RESULTS AND DISCUSSION

Everything reported in the demographic table is a result of studying participants who took part in the application's effectiveness and function testing. It includes information about people's gender, age, race and the type of work they do. To avoid any issues in the evaluation process, collecting this information ensures that users are from the target audience planned for the project. It offers some assistance in properly executing the project and ensuring that the users are correctly represented by the testers (Darcy et al., 2010; Seow & Sanmargaraja, 2015; Shalini Sanmargaraja & Seow, 2018).

Table 3.0: Gender, Age, Race, Occupation

Gender	**Quality**	**Total %**
Male	35	56.5
Female	27	43.5
Age	**Quality**	**Total %**
18 – 20	8	12.9
21 – 24	34	54.8
25 Above	20	32.3
Race	**Quality**	**Total %**
Malay	49	79.0
Indian	6	9.7
Chinese	7	11.3
Occupation	**Quality**	**Total %**
Student	41	68.3
Employee	19	31.7

3.1 Mean Scale Interpretation

Mean scale interpretation is applied to present the research findings about the effectiveness, how the application functions, its User Interface, and User Experience collected in Piaigrove. This answer comes from data collected using a five-point Likert scale and the options are Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. This approach makes it possible to understand what users think and evaluate the application's success (Ziyadin et al., 2019).

Table 3.1 : Mean Scale Interpretation

Average Mean	**Interpretation of Mean**
1.00 - 2.00	Strongly Disagree
2.01 - 3.00	Disagree
3.01 - 4.00	Agree
4.01 - 5.00	Strongly Agree

3.1.1 User's View on User Interface

All the arguments involve the proper use of the Piaigrove application's visual design, such as the buttons, the choice of colors, images, and graphics. The fact that the mean value is high demonstrates that users are generally happy with the prototype's visual looks, color choices, the arrangement of buttons, how data is organized, and all the graphics used in it. The results prove that the application's user interface and user experience were rolled out successfully.

Table 3.1.1: Mean Scale Interpretation

No	Criteria	Mean	Interpretation
1	Layout is consistent	4.41	Strongly Agree
2	The application is very responsive	4.45	Strongly Agree
3	The transition of the application is smooth	4.34	Strongly Agree
4	Interactive elements (buttons) are easy to identify	4.39	Strongly Agree
5	Interactive elements (buttons) are easy to use	4.43	Strongly Agree
	Total	4.40	Strongly Agree

3.1.2 Usability and Functionality On User Experience

Every case looks into the Piaigrove application's use, the way users experience it, how content is set up, and how pleased users are with it. Since the study gave a high mean value, it is clear that the prototype of the Piaigrove application offers a good quality of service and satisfies users well. From this it can be seen that users find the application is very effective and satisfactory to use.

Table 3.1.2 : Mean Scale Interpretation

No	Criteria	Mean	Interpretation
1	Users can use features easily	4.31	Strongly Agree
2	The application functions well	4.41	Strongly Agree
3	The application works without error	4.45	Strongly Agree
4	The system operates smoothly and responds to user input	4.34	Strongly Agree
5	The application is user-friendly	4.39	Strongly Agree
	Total	4.39	Strongly Agree

3.1.3 Experience (Effectiveness) Of Users on The Existence of The Piaigrove Mobile Application.

Every item that examines how the Piaigrove application functions and works for users shows a high average rating. The fact that the mean is high during analysis suggests that the Piaigrove application has very good functionality and users are satisfied with it. This underlines that in general, users are happy with the way this application works and that its performance is high (Pundlik et al., 2023).

Table 3.1.3 : Mean Scale Interpretation

No	Criteria	Mean	Interpretation
1	The application can facilitate the learning process	4.47	Strongly Agree
2	The application has clear and accurate information	4.35	Strongly Agree
3	The application provides a clear explanation	4.39	Strongly Agree
4	Overall, I am satisfied with the application	4.44	Strongly Agree
	Total	4.40	Strongly Agree

Figure 3.1.3: Application Piaigrove

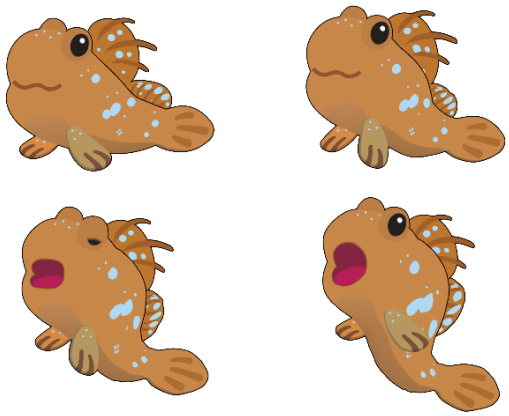

Figure 3.1.4: Mudskipper persona virtual tourist guide

Figure 3.1.4 show the mudskipper, a native species, acts as an educational and symbolic helper, introducing users to all about the nature and ecological relevance of the park. Since it spends its life both on land and in water, the mudskipper stands for adaptability and working well in ecological harmony. This makes it a good fit for helping at the park by sharing information and details as needed (Ramsar Convention Secretariat, 2003).

4.0 CONCLUSION

All in all, Piaigrove demonstrates that virtual assistants can play a major role in enhancing visitors' experiences at natural parks. Piaigrove's virtual assistance and environmental learning methods make tourism more available to all while keeping the visit meaningful. (Bartie et al., 2018). With this project, we point to how technology can open up ecotourism to more people and help prepare the way for new developments in digital heritage and nature interpretation. (Ziyadin et al., 2019).

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Enhancing Local Community Business Through Digital Marketing Videos

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ABSTRACT

In today's fast-paced digital era, social media has become a key platform for promoting products and services, especially for small businesses and local communities. Many entrepreneurs have begun to realize the vast potential of digital marketing in increasing brand visibility and attracting more customers. However, there are still community businesses that have not fully leveraged these advantages. Therefore, this study was conducted to develop promotional videos aimed at enhancing local community businesses, specifically the Pineapple Fiber Thread Business M&Z, through the use of digital marketing strategies. A qualitative approach was used to evaluate the effectiveness of five promotional video series uploaded on YouTube and Instagram. Data were collected based on user interactions such as the number of likes, shares, comments, viewers and subscriptions. The findings indicate that digital videos have the potential to significantly increase the visibility and competitiveness of local community businesses on social media, thus expanding market reach and supporting local economic growth. In summary, the video serves as an impactful instrument for cultural branding, connecting history with the present, and illustrating how heritage aligns with contemporary values of sustainability and cultural respect.

Keywords: cultural branding, digital marketing, pineapple fiber, social media, video.

1.0 INTRODUCTION

1.1 Digital Marketing

Digital platforms have indeed played a central role in this story, to the point where scholars speak of a “platformization of cultural production” (Nieborg & Poell, 2018). In marketing communications, messages in digital content promoted through media can include images, videos, photos, or infographics (Retnasary et al., 2019). This promotional content systematically conveys ideas and thoughts to customers and focuses on creating product materials to be sold via the Internet or other digital media (Husna, 2019). In the digital era of information, content control is crucial for disseminating information about tourism in an area through media and information technology. Departing from these concepts and phenomena, this research will focus on digital content-based video creation training to enhance the promotional capabilities of pineapple fiber (Afham D. 2022). Digital marketing is a way to promote certain products using internet media such as social media, Facebook, Instagram, YouTube, Line, or other social media (Adiyono, N. G. 2021). The problem faced by M&Z is that there are still community businesses that have not fully leveraged these advantages. Because M&Z has a small community in Pontian, they are unaware that pineapple fiber can be a product. The solution to the problem is promoting digital marketing videos on M&Z's YouTube channel. Creating a series of videos, such as M&Z's background, workplace, training and workshops, pineapple fiber products, sambal hitam nanas, and successful M&Z.

Figure 1: Info about M&Z and pineapple fiber

M&Z Pineapple Fiber Yarn Business is a small and medium enterprise (SME) operating in Pontian, Johor, specifically in Kampung Rimba Terjun. Founded by Puan Munah Binti Kadir and her mother, Hajah Rafiah Binti Mat Taib, this business focuses on producing yarn from pineapple leaf fiber manually, maintaining traditional techniques that have been passed down through generations (Figure 1). Cultivation of pineapple in Malaysia produces wastes such as leaves and crown, where these wastes are discarded or left in the field. A systematic pineapple leaf fiber (PALF) extraction method was designed to maximally utilize this waste and make pineapple plantations more sustainable (Munthoub, D. I. 2021). Acquiring pineapple fiber consists of multiple traditional and precise processes that demand dedication. Initially, the chosen pineapple leaves, typically following the fruit harvest, are gathered and cleansed of dirt and sharp spines. Subsequently, the leaves are scraped with specialized instruments like a flat knife or a traditional scraper to extract the fibers concealed within them. Fibers are collected, cleaned, dried, and twisted into yarn, promoting eco-friendliness and utilizing agricultural by products for textiles. M&Z leverages agricultural waste, creating products that highlight traditional techniques and attract cultural interest. Apart from producing pineapple fiber yarn, M&Z Pineapple Fiber Yarn Business in Pontian, Johor, also offers various pineapple fiber-based products and food products such as pineapple black sauce. This venture not only sustainably utilizes local resources but also introduces innovation in craft and culinary products.

2.0 METHODOLOGY

This study uses qualitative methods to look at how CDIO (Conceive, Design, Implement, Operate) digital marketing videos can help small businesses in the community. It explores the process and benefits of using these videos to enhance the visibility and operations of local businesses. The research strategy and empirical methods outline the general approach along with specific techniques aimed at achieving the research objectives. It also addresses the research design and the approaches utilized for selecting research participants and gathering data. The rationale behind the development of the process for generating theory, which serves as the procedural framework for conducting research, is referred to as the research methodology. This methodology delineates the essential principles for organizing, planning, designing, and executing research. The research paradigm that a researcher chooses to follow influences methodological decisions. This paradigm not only directs the selection of data collection and analysis methods but also the choice of competing conceptual approaches (Mohajan, H. K. 2018). Research involves exploring materials to verify facts, requiring a solid methodology for effective investigation. As a result, the research techniques include the design of the study, the origin of the study data, and the means of gathering data. The CDIO framework, originally for engineering education, has been extended to other fields (Fahlgren et al. 2018).

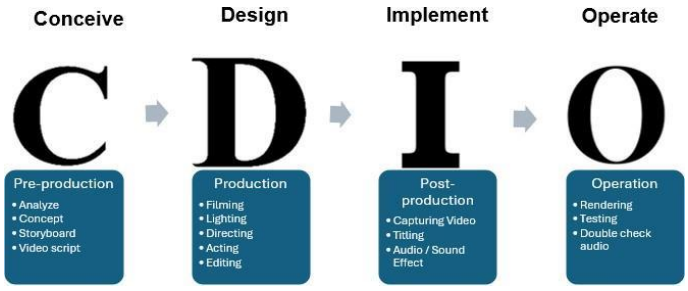

Figure 2: CDIO framework

CDIO is an innovative framework for engineering education. It is an approach to continuously strengthen knowledge and professional skills required by engineering graduates. The approach provides a platform for active and experiential learning for students (Peter G., 2012). The Conceive phase identifies the problem and sets goals for the project (Figure 2). A local pineapple fiber firm lacks good promotional tools. Project goals include creating digital marketing videos to boost business visibility and product awareness. This phase involves extensive research to understand the target demographic and evaluate digital marketing's impact on local businesses. Since promotional efforts are lacking, the team uses YouTube and Instagram to reach more people. The Design phase builds on the Conceive phase. Creative components of advertising videos are developed here (Roy, D. 2022). This requires creating video concepts, scripts, and storyboards that describe the product and its features (Aini, 2020). The design phase focuses on creating engaging, visually appealing, and digital marketing strategy-aligned video content. The purpose is to stress the product's sustainability and connection to local culture in the film to attract buyers and meet digital marketing goals.

Design concepts are implemented through production in the Implementation phase. This procedure involves video filming, lighting setup, scene direction, and high-quality footage that highlights the product's key qualities (Leboreiro, D. L. 2024). The team checks each shot against the storyboard and concept during filming and makes tweaks. Team members work together to optimize video capture for pineapple fiber product promotion in this phase. Operate prioritises post-production and distribution. Post-production editing optimizes the video for social media. This includes sound, music, and visual effects (Ismail, O. A. 2025). After production, the video is uploaded to YouTube and Instagram for viewing. The video's views, likes, comments, and shares are tracked during this phase (Munaro, A. C 2021). These interactions help the team evaluate the video's efficacy and improve future material. This step maximises the video's reach and goals of local business promotion and interaction (Juanna, 2024). This organised strategy ensures the initiative is original and strategically organised, optimising digital marketing for local businesses.

3.0 RESULTS AND DISCUSSION

The CDIO (Conceive, Design, Implement, Operate) framework offers a structured approach to managing video production projects by integrating engineering-based thinking into creative workflows. In the context of video creation, the pre-production phase aligns with the "conceive" and "design" stages, focusing on idea development, scriptwriting, storyboarding, and resource planning. During the production, corresponding to "Implement," the video is filmed or animated following a structured plan. Finally, post-production represents the "Operate" phase, where editing, sound design, effects, and final rendering take place, preparing the video for

distribution and audience engagement. The application of the CDIO model to video production produced many noteworthy results. Teams showed improved planning and communication during pre-production. There were fewer delays because storyboards and scripts were more in line with the project's objectives. Smoother shoots, fewer reshoots, and more effective use of time and equipment were all results of the planned preparation during the production phase. Teams were able to predict editing requirements ahead of time in post- production, which resulted in faster turnaround times and higher-quality videos. Additionally, the process demonstrated improved team accountability and more equitable workload distribution. Applying CDIO in video production encourages a balance between creativity and structure. While traditional video projects often rely heavily on artistic intuition, the CDIO model brings a disciplined framework that enhances planning, risk management, and technical execution. One of the most impactful benefits observed was how the “Conceive” and “Design” phases reduced issues downstream, proving that thorough early planning leads to smoother production and post-production stages. Additionally, by emphasizing continuous evaluation and user feedback in the "Operate" stage, teams were able to adjust their outputs to better meet audience needs. Despite some initial resistance due to its engineering origin, the CDIO model proved highly adaptable and beneficial in creative video production settings.

Making a video consists of three crucial phases: pre-production, production, and post-production. Pre-production establishes the foundation, encompassing concept creation, screenplay writing, and organizing, tackling the “who, what, where, when, and how,” which involves choosing locations and casting actors. Getting ready for an occasion, making sure every aspect is arranged before shooting starts. Production is the dynamic stage where designed concepts are realized; cameras begin filming, actors deliver performances, and the crew records scenes, arranging lights and fine-tuning sound. This phase captures the thrill of where creativity converges with implementation. Post-production ensues, converting raw footage into the finished product through editing, organizing, and refining. Sound effects, music, and voice-overs are incorporated to elevate the story. This phase is like assembling a puzzle, leading to a unified, attractive video. Every stage is essential, playing a role in creating a final product that conveys the intended message. In the pre-production phase, “Conceive”, the success of a video promoting pineapple fiber depends on thorough research, design, ideation, scriptwriting, and storyboarding. The research design phase involves understanding the target audience through demographic and psychographic studies, competitive analysis, and trend research, helping to shape a video that speaks to consumers' values, especially around sustainability. In ideation, creative concepts are developed, with a focus on delivering a message that ties pineapple fiber to eco-consciousness and cultural significance. Ideas might range from a promotion-style video to a more playful, viral-style short clip for social media. The scriptwriting phase refines these ideas into a structured narrative, ensuring the video has a clear message that connects emotionally with the audience while highlighting the benefits of pineapple fiber. This includes embedding culturally relevant references to resonate with the target market. Finally, the storyboarding process brings the script to life visually, mapping out each shot and ensuring that the video aligns with digital marketing goals.

Figure 3: Scriptwriting & Storyboard

The subsequent stage involves the cast and crew, which includes individuals from pre-production, production, and post-production, organized as illustrated in the diagram above, based on the research outcomes. The pre-production process includes elements such as the synopsis, storyboard, and scriptwriting, among others. Figure 3 illustrates the scriptwriting activity being typed in Microsoft Word and presents a storyboard created with Adobe Illustrator. In the production phase “Design”, this stage involves capturing high-quality video that showcases the pineapple fiber in an engaging and visually appealing manner. The challenge lies in balancing the promotion of the product’s sustainability and innovation with the broader cultural message. Highlight pineapple fiber's connection to local craftsmanship and traditions; use social media for feedback to enhance brand authenticity.

Figure 4: Shooting & Editing Process

Next is the production phase, which involves filming, organizing, and editing the footage. Shooting captures a scene based on a storyboard that details the shot type and the item or product intended for the audience. Figure 4 illustrates the shooting process. Sorting entails selecting high-quality footage and pairing it with suitable audio and sound. The subsequent phase, "Implement," refers to the editing procedure, where all the video and audio recordings are compiled into the final version of the video. Editing was the responsibility during the production process. The post-production phase, "Operate," focuses on editing and refining the video content to align with the digital marketing strategy. This includes ensuring the final product is optimized for various social media platforms, whether for YouTube or Facebook. Long-form content for YouTube is critical for enhancing engagement and viewership. Social media metrics optimize videos for virality, and data analytics enhance performance evaluation.

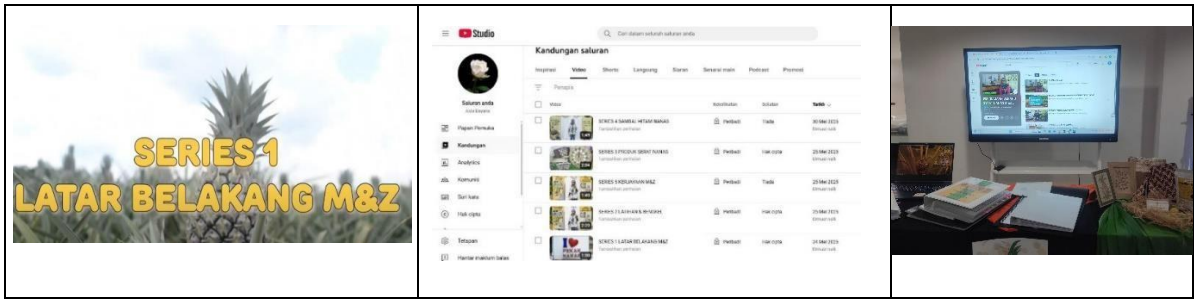

Figure 5: Rendering and Testing

Figure 5: A YouTube video series episode on the allocation of promotional videos. In the last stage, the concluding video. The platform chosen was YouTube, which serves as a medium for promoting and sharing videos for distribution. The platform offers features referred to as YouTube Studio, allowing us to oversee all the videos on the channel. We evaluate videos on the YouTube channel based on likes, comments, subscribers, views, and shares.

Table 2: The Frequency of Like, Comment, Share, Subscriber & View

Video	Likes	Comments	Shares	Views	Subscribers
URL:https://youtu.be/AgurYPqvuc8	6	2	4	22	2
URL:https://youtu.be/PlW3yy6rYhs	5	0	4	12	2
URL:https://youtu.be/9dxfQsBoOyY	3	0	3	22	2
URL: https://youtu.be/2AqAg1N5nSM	0	0	3	0	2
URL: https://youtu.be/XQ1hLrH20j0	0	0	2	12	2

Based on Table 2, the Enhancing Local Community Business Through Digital Marketing Videos was done on YouTube. Five videos were selected on YouTube with Pineapple Fiber content that has a low level of public interaction (low number of views, likes, comments), including Video 1 entitled "Latar Belakang M&Z" (6 like, 2 comment, 4 share, 2 subscriber, 22 views, until 24 May 2025), Video 2 entitled "Latihan & Bengkel" (5 likes, 0 comments, 4 shares, 2 subscribers, 12 views), Video 3 entitled "Produk Serat Nanas" (3 likes, 0 comments, 3 shares, 2 subscribers, 22 views), Video 4 entitled "Sambal Hitam Nanas" (0 likes, 0 comments, 3 shares, 2 subscribers, 0 views), and Video 5 entitled "Kejayaan M&Z" (0 likes, 0 comments, 2 shares, 2 subscribers, 12 views). The sample taken was 22 viewers for each video, leaving a digital footprint in the video. For the responder's comment on YouTube video series 1, "Latar Belakang M&Z", two commenters in the YouTube section provided encouraging and reflective remarks regarding the video. The first commenter reacts by saying, "Wow." The second responder highlighted improvement based on lighting, camera angle, and audio gain. They recommended examining related themes in upcoming uploads and motivated the creator to keep generating educational material. Both remarks demonstrated authentic involvement and added to a positive environment in the comments section.

4.0 CONCLUSION

In conclusion, the videos underperformed due to limited views, few likes, no comments, unengaging titles and thumbnails, misaligned content, poor timing, and competition. The absence of promotion or lack of interaction with the audience also contributes to weaknesses in terms of engagement. Therefore, improvements regarding marketing strategy, quality of delivery, and a deeper understanding of the audience need to be considered in an effort to increase responses in a month or two.

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Fun Paws and Learn: Interactive Learning Kiosk Application Development at Zoo Johor

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ABSTRACT

This study focused on identifying the essential elements needed for an interactive learning kiosk at Zoo Johor and developing it as an effective edutainment tool. Traditional methods of conveying information, such as static posters and boards, were found to be ineffective, particularly for younger visitors like children and teenagers who are accustomed to more engaging digital experiences. The objective was to develop and analyze the effectiveness of the interactive learning kiosk for Zoo Johor. The method used to develop this interactive learning kiosk can be classified as a User-Centred Design (UCD) approach; research and planning, design and development, prototyping and testing, final implementation, and future implications. The method is quantitative by collecting data, assessing five key constructs, which is ease of use, design and visual appeal, interactive features, navigation and content, and sound and music. It can be concluded that the kiosk was engaging, and the overall interpretation was positive, with high means in the following categories: Ease of Use (Mean = 4.56), Design and Visual Appeal (Mean = 4.56), Interactive Features (Mean = 4.48), Navigation and Content (Mean = 4.55), Sound and Music (Mean = 4.49), and Overall Satisfaction (Mean = 4.58). The analysis revealed high satisfaction levels across all areas, with visitors particularly appreciating the intuitive navigation and engaging multimedia content. The quizzes and interactive videos were effective in maintaining visitor interest and encouraging active participation. Features such as quizzes, animal facts, and interactive videos successfully captured and maintained visitors' interest, especially among children and teenagers. The interactive kiosk, combining educational and entertainment elements, proved to be an effective edutainment tool at Zoo Johor. Interactive technology increased visitor engagement and facilitated more appealing and efficient information delivery. Therefore, developing and implementing such kiosks is highly recommended to enhance visitor learning experiences and promote awareness of animal conservation in zoos.

Keywords: interactive learning, learning technology, kiosk, zoo education, edutainment.

1.0 INTRODUCTION

The project is to revitalize Zoo Johor to enhance its role as a centre for learning and entertainment at the same time by integrating modern technology to attract and engage contemporary visitors, especially the younger generations. Being one of Malaysia's oldest zoos, Zoo Johor struggles to keep up with newer attractions because it still relies on traditional methods like posters and static boards, which do not capture the attention of kids and teens (Ballantyne & Packer, 2011). To address this, the project is to create an interactive learning kiosk that combines education and entertainment, or gamification, to make visits more enjoyable while also raising awareness about wildlife conservation and biodiversity. Research shows that interactive tools like digital games and multimedia kiosks can boost motivation, engagement, and learning much better than static displays (Falk & Storksdieck, 2010; Hamari et al., 2014; Dichev & Dicheva, 2017; Hamari et al., 2020). The project focuses on designing user-friendly kiosks that everyone can easily use and aims to see how well these kiosks improve visitors' knowledge and awareness about conservation. Data is being gathered through interviews and on-site observations, and prototype testing will happen next semester, with the

hopes that these ideas will help make learning at Zoo Johor more fun and effective with the help of modern technology.

2.0 METHODOLOGY

According to Lindsay Derby, user-centered design (UCD) is an iterative design approach: research, align, build, test, and iterate (Figure 1) that is fundamentally driven by making decisions based on the user's needs. In this process, designers first need to research to fully grasp what the use case is and what users expect. A designer aims to mix business, and user needs to design a final solution. Also, according to Lindsay Derby, empathy with users is an essential part of user-centered design, and the approach should also fit the needs of any company or client. The design solutions are said to be stronger after repeated tests with either actual or future users. Research, align, build, test, and iterate.

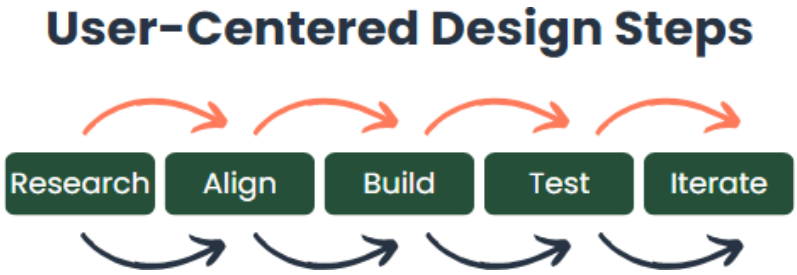


Figure 1: (Source: User-Centered Design: What it is and how to do it Right, 2022)

The first step of this method, user-centered design (UCD), is research, which involves gathering insights into the target users and understanding their behaviors, needs, and pain points. According to the Interaction Design Foundation (2016), user interviews, surveys, and observations to determine user needs and difficulties; the design team gathers data. This fundamental stage guarantees that the design is influenced by actual user problems and experiences. Before beginning the design process, user research serves as the basis for comprehending the usage context and user needs. Following this, the align phase synthesizes the research findings to ensure that all the stakeholders have a unified understanding of the project's goals and the users' needs. This step also includes defining user personas by setting key objectives and prioritizing the features to be developed. This alignment guarantees that everyone involved understands the needs of the user and the design's direction. To guarantee that the design successfully satisfies user needs, alignment is essential, according to the Baymard Institute (Baymard Institute, n.d.).

In the build phase, prototypes, wireframes, or mock ups are created from the design concept. The design team gets to work creating solutions that cater to the users' needs that have been determined. To ensure alignment with user requirements, ScienceDirect states that this process entails developing and improving the product based on user feedback (ScienceDirect, n.d.). To find usability problems, the design is tested with actual users during this phase. The input obtained aids in determining how effectively the design satisfies user requirements and points out areas in need of development. To create products that satisfy customer demands and preferences, usability testing at every stage of the design process is a useful strategy, claim (Becker and Yannotta, 2015). The design is improved and refined based on input received after testing. Due to the cyclical nature of this approach, the design team can go back and improve the solution based on feedback from the real world by revisiting any previous phases (Research, Align, Build, Test). ScienceDirect (n.d.) defines user-centered design as a process that

incorporates people at every level of product development to produce goods that satisfy their needs.

In the testing phase, the questionnaire is part of a study aimed at improving the Interactive Learning Kiosk at Zoo Johor. This study's main objective is to collect input on the kiosk's usability, content efficacy, and general user happiness to improve visitors' educational experiences. Children between the ages of 7 and 12, as a convenience sampling, are included in the study's target audience, as shown in the questionnaire's first section when participants are asked to identify their age group. The purpose of the survey is to evaluate younger users' interactions with the kiosk, with an emphasis on their general impressions of its features and capabilities. The survey uses a set of questionnaires which is divided into three sections that start with demographic information. This section is to collect details and data such as the participant's age of group, gender, and level of interest in animals and nature. Knowing this information is crucial to comprehending how various user backgrounds could affect how they view the kiosk. In Section 2, which is devoted to the user experience, participants are asked to score several elements of the kiosk on a Likert scale that goes from "Strongly Disagree" to "Strongly Agree". This section's questions assess things like ease of use, design and visual appeal, interactive features, navigation and content, and sound and music experience. By getting input on these components, the study hopes to pinpoint the kiosk's functionalities and interface's strong points and potential areas for development.

Assessing users' general happiness with the kiosk is the goal of Section 3 of the survey. Participants are asked to rate how well the kiosk taught them about animals, if they would suggest it to others, and whether the experience increased their interest in wildlife. Because the study takes a quantitative approach, numerical data that can be statistically examined can be gathered. By using this technique, the researcher can find patterns and trends in user feedback, which can be utilized to inform data-driven choices on upcoming kiosk enhancements. More interesting, instructive, and user-friendly features for the Interactive Learning Kiosk at Zoo Johor will be improved based on the insightful input gathered from this questionnaire. The first step in using SPSS to evaluate the data gathered from the questionnaire is entering the survey answers into the program. Data may be categorized appropriately because the questionnaire is designed to collect demographic data and replies on a Likert scale. Age group and gender are examples of demographic data that will be treated as categorical variables, but the Likert scale responses (which range from "Strongly Disagree" to "Strongly Agree") will be treated as ordinal data. The next step after entering the data into SPSS is to make sure the dataset is accurate and tidy by looking for any missing values or inconsistencies. Descriptive statistics can be used for the user experience section analysis to give a broad picture of the responses. For every item, frequencies, percentages, means, and standard deviations must be determined. This will make it possible for academics to comprehend general patterns in design, interactive features, content, simplicity of use, and user pleasure. To obtain more profound understanding, correlation analysis may be employed to detect any noteworthy connections between user experience elements and general kiosk satisfaction, while inferential statistics like chi-square tests may be employed to investigate associations between demographic variables (e.g., age group and satisfaction level).

Comparable methods can be used to examine how participants evaluated the kiosk's entire experience and educational value for Section 3, which focuses on overall user satisfaction. With the help of SPSS, researchers can do mean comparisons to determine whether some kiosk features or elements received higher ratings than others. Furthermore, it is possible to perform

statistical tests to ascertain whether there are any noteworthy distinctions among different demographic groups, offering important information on how diverse people engage with the station. All things considered, utilizing SPSS to examine the data from the questionnaire will offer a numerical framework for assessing the kiosk's functionality, determining its advantages and disadvantages, and guiding enhancements. To improve user experience and engagement at Zoo Johor, the researchers can identify trends and patterns by conducting these statistical studies. These findings will aid in optimizing the kiosk's design and operation.

3.0 RESULT AND DISCUSSION

The user-centered design (UCD) methodology used in the creation of an interactive learning kiosk for Zoo Johor comprises the following crucial stages: research, alignment, build, test, and iterate. To guarantee that the kiosk not only satisfies the educational goals but also offers users enjoyable and easy-to-use experience, each stage is essential. Surveys, interviews, and observational studies are used in the research phase to acquire information about the preferences, learning preferences, and degree of technological comfort of Zoo Johor's guests. The kiosk's design and content are informed by this study, which makes sure that it considers users' educational needs as well as their degree of comfort using interactive technology. To specify the kiosk's goals and features, the Align phase concentrates on bringing all parties involved, including Zoo Johor employees, designers, developers, and content producers, in line. This cooperative effort guarantees that the objectives, user expectations, and technological specifications are comprehended and followed. It also lays the groundwork for the kiosk's development by addressing limitations including budget, schedule, and technology. Both the software development and the physical design of the kiosk are completed during the Build phase. Software is created to incorporate instructional materials like animal information, videos, and interactive games, and hardware, like touchscreens and multimedia displays, is put together. This stage is directed by the earlier research, guaranteeing that the design is aesthetically pleasing, user-friendly, and captivating.

Figure 2: Interviews and observation with a Zoo Johor employee.

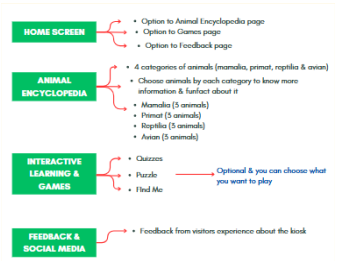
Figure 3 both the software development and the physical design of the kiosk are completed during the Build phase. Software is created to incorporate instructional materials like animal information, films, and interactive games, and hardware, like touchscreens and multimedia displays, is put together. This stage is directed by the earlier research, guaranteeing that the design is aesthetically pleasing, user-friendly, and captivating.

To make sure the kiosk works as planned, user testing is done throughout the test phase. By interacting with the kiosk, visitors evaluate its technical performance, content engagement, and usability. Feedback from this stage aids in identifying any areas that need improvement, such

as information that may require more explanation or navigational problems. This guarantees that before the kiosk is made available to the general public, it is completely operational and user-friendly. The Iterate phase, which comes after production, is where user input is gathered and the kiosk is continuously observed. Continuous enhancements are possible during this phase in response to visitor interactions, usage statistics, and changing educational requirements. To maintain the learning experience current and applicable for future visits, the kiosk's capabilities are regularly improved through the addition of new content or software upgrades.

The results from the kiosk evaluation indicate high levels of visitor engagement and satisfaction across several key areas, confirming the effectiveness of the interactive learning kiosk at Zoo Johor. The categories that scored particularly well were Ease of Use (Mean = 4.56), Design and Visual Appeal (Mean = 4.56), and Overall Satisfaction (Mean = 4.58), all of which highlight the kiosk's intuitive interface and user-friendly design. Visitors found the kiosk's navigation simple and efficient, facilitating a smooth learning experience. The Interactive Features (Mean = 4.48) and Sound and Music (Mean = 4.49) also received strong ratings, reflecting the success of the multimedia elements in making the learning process enjoyable and immersive. These features, including quizzes, games, and engaging sound effects, were integral in keeping visitors, particularly younger audiences, entertained while reinforcing the educational content.

The high mean scores across all categories suggest that the kiosk was not only effective in meeting its educational goals but also succeeded in engaging visitors. The positive feedback emphasizes the kiosk's role in enhancing the overall zoo experience by providing a dynamic and enjoyable learning platform, with success in interactive elements and user interface design. This feedback sets a strong foundation for future improvements and adaptations to further enhance user engagement and educational impact

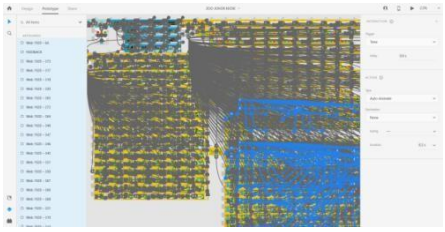


a) Site Map

b) Background development

c) Wire-frame

d) Chatracter study



UI and UX development

UI and UX development

Figure 3: Process development of Interactive Learning Kiosk for Zoo Johor

Table 1: Mean and interpretation of mean score (Santipap Upara, 2023)

Interpretation of Mean Score	
1.00- 1.74	Not at all
1.75-2.49	Low
2.50-3.24	Average
3.25-4.00	High

Table 2: Demography

Items	Frequency (N=45)	Percent (100%)
Age		
7-8	11	24.4
9-10	16	35.6
11-12	18	40.0
Total	45	100
Gender		
Boy	29	64.4
Girl	16	35.6
Total	45	100
Like Animal		
A lot	22	48.9
I like them	17	37.8
A little	5	11.1
Not much	1	2.2

The table 2 shows the demographic breakdown of 45 participants, focusing on their age, gender, and how much they like animals. Most of the participants were between 9-12 years old, with a slight majority (40%) being in the 11-12 age group, followed by (35.6%) in the 9-10 years group and (24.4%) in the 7-8 years group. In terms of gender, there were more boys (64.4%) than girls (35.6%). when it comes to animals, the majority of participants like them, with 48.9% saying they like them a lot, and 37.8% saying they like them somewhat. Only a few participants (11.1%) said they liked animals just a little or not at all.

Table 3: UX

Item	Mean	Interpretation
Ease of Use		
It was easy to find what I wanted on the kiosk.	4.73	High
The screen worked quickly when I touched it.	4.53	High
The menu was easy to understand.	4.53	High
I could easily get back to the home screen if I got lost.	4.46	High
The kiosk worked without any problems.	4.58	High

Design and Visual Appeal		
The kiosk looked fun and friendly.	4.64	High
The colours on the screen made me feel happy.	4.51	High
The writing was big enough for me to read easily.	4.55	High
The design was bright and colourful, but not too over.	4.53	High
I liked the layout of the kiosk screen and how everything was arranged.	4.55	High
The kiosk looked fun and friendly.	4.64	High
Interactive features		
I enjoyed playing the games on the kiosk.	4.58	High
The quizzes help me learn more about animals.	4.49	High
The videos were interesting and fun to watch.	4.42	High
The games and quizzes were easy to play.	4.40	High
I liked that the kiosk had both games and learning.	4.49	High
Navigation and Content		
I liked the way the information was shown.	4.73	High
The information was shown in a way I could easily understand.	4.49	High
The information on the kiosk was fun and not too boring.	4.49	High
I did not get confused while using the kiosk.	4.44	High
The sound of the animal is interesting.	4.62	High
Sound and Music		
The sound effects during the games and videos were fun to hear.	4.44	High
The music or sound made the experience more enjoyable.	4.6	High
The sound did not distract me from what I was trying to do on the kiosk.	4.53	High
I liked the sound effects when I touched the screen or clicked the buttons.	4.40	High
The sound and music made me happy while using the kiosk	4.60	High
Overall Satisfaction		
I am happy with how the kiosk.	4.73	High
The kiosk helped me learn about animals and the zoo.	4.51	High
I would tell my friends to use the kiosk.	4.46	High
The kiosk made me more interested in learning about wildlife.	4.42	High
The kiosk was fun and entertaining at the same time.	4.75	High

All evaluations of the kiosk in Table 3 showed that users were very happy across every area. Users stated that the kiosk was simple to use, scoring it highly for item finding (4.73) and screen speed (4.53). People using the app mentioned that they could always return to the home screen easily (mean = 4.46) and did not experience any technical problems while using it (mean = 4.58). Many users in the Design and Visual Appeal category said they found the kiosk design

appealing and cheerful (mean = 4.64) and that the colorful screen brought them a positive feeling (mean = 4.51). Many people found the size of the text suitable for reading (mean = 4.55), and they approved of the layout of the kiosk (mean = 4.55). The design, which was both bright and colorful, was appreciated by users because it stood out clearly without seeming too intense (mean = 4.53). Regarding interactive features, users rated the games, quizzes, and fun videos very positively (game: mean = 4.58, quizzes: mean = 4.49, videos: mean = 4.42). They indicate that using the interactive elements of the kiosk was successful in keeping people interested and making the experience pleasant. According to users in the Navigation and Content category, finding and understanding the information was simple (mean = 4.73). The majority of the group said they did not find the kiosk confusing (mean = 4.62). Sound and Music received positive ratings for Sound Effects in and out of the games (mean 4.44) and for the way Music and Sound blended in (mean 4.60). Figure 6 tells us that the audio elements made users feel more positive. Users also gave very positive reviews for the Overall Satisfaction, rating the kiosk highly for its functionality (mean = 4.73). People found the educational content on the kiosk was useful (mean value = 4.51) and they liked mixing fun with educational content (mean value = 4.75). All in all, the evaluation found that the kiosk delights users by bringing together education and entertainment.

Table 4: Mean and level score of each construct

Construct	Mean	Level
Ease of Use	4.73	High
Design and Visual Appeal	4.49	High
Interactive Features	4.49	High
Navigation and Content	4.44	High
Sound and Music	4.62	High
Overall Satisfaction	4.73	High

4.0 CONCLUSION

In short, Zoo Johor's interactive learning kiosk was very effective, adding both education and entertainment value to the visitor experience. The kiosk met the requirements of various people by applying a User-Centered Design (UCD) methodology, with main attention on young visitors, families, and children. What the surveys, interviews, and on-site observations showed was that people found the kiosk user-friendly, attractive, enjoyable, and offering a variety of multimedia features. The fact that Ease of Use (4.73), Design and Visual Appeal (4.64), and Overall Satisfaction (4.75) all scored high means visitors found the kiosk to be easy, informative, and enjoyable. Because games and quizzes kept their attention engaged, visitors gained a better understanding of wildlife conservation. It shows that interactive technology helps visitors participate more, which improves how much they learn at the zoo. Because of this, it is suggested that Zoo Johor and similar organizations make use of such kiosks for their teaching and preservation work.

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Penerokaan Kaedah Interaktif Berasaskan Realiti Maya untuk Mengajar Huruf Vokal Bahasa Melayu kepada Murid Pemulihan

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ABSTRAK

Seramai 122,000 murid Tahun Satu bagi sesi akademik tahun 2024 di seluruh negara dikesan masih belum menguasai kemahiran membaca. Murid-murid ini telah dikenalpasti dan perlu mengikuti kelas pemulihan. Murid pemulihan yang lemah dalam literasi asas sangat memerlukan pendekatan pengajaran yang lebih interaktif dan menyeronokkan. Namun, kaedah konvensional yang masih meluas digunakan bersifat kaku, kurang elemen visual serta tidak melibatkan aktiviti menarik, menyebabkan murid mudah hilang minat dan tumpuan. Hal ini menyukarkan mereka memahami konsep asas seperti mengenal huruf vokal. Oleh itu kajian ini bertujuan membangunkan bahan pembelajaran interaktif berasaskan realiti maya (VR) yang direka khas untuk murid pemulihan serta mengumpul maklum balas guru terhadap penggunaannya dalam membantu murid menguasai kemahiran membaca Bahasa Melayu. Kajian ini menggunakan pendekatan kualitatif melalui pemerhatian dan temu bual bersama dua orang guru dan murid selepas pelaksanaan VR dalam sesi pengajaran. Hasil kajian menunjukkan bahawa penggunaan Realiti Maya (VR) sebagai alat bantu mengajar memberi kesan positif terhadap keberkesanan pelaksanaan sesi pengajaran, di mana murid menunjukkan penglibatan dan pemahaman yang lebih baik. Selain itu, guru juga memberikan maklum balas positif terhadap inovasi pengajaran ini, menyatakan bahawa VR meningkatkan minat dan keberkesanan pengajaran mereka. Secara keseluruhan, penggunaan VR berpotensi menjadi alat bantu mengajar yang berkesan dan inovatif dalam memperkukuh penguasaan membaca murid pemulihan serta menyokong transformasi pendidikan abad ke-21.

Kata Kunci: alat bantu mengajar, huruf vokal, kemahiran membaca, murid pemulihan, realiti maya

1.0 PENGENALAN

1.1 Pendahuluan

Kemahiran membaca merupakan salah satu asas penting dalam pendidikan awal, khususnya bagi murid-murid sekolah rendah. Tanpa penguasaan yang kukuh terhadap kemahiran membaca, murid akan menghadapi kesukaran dalam memahami dan mengikuti pelajaran di peringkat yang lebih tinggi. Namun, kajian menunjukkan bahawa masih terdapat ramai murid, terutamanya yang mengikuti kelas pemulihan, yang mengalami masalah dalam menguasai kemahiran membaca dengan baik, terutamanya dalam pengenalan huruf vokal dalam subjek Bahasa Melayu. Kelemahan ini sering disebabkan oleh pendekatan pengajaran yang kurang berkesan dan tidak cukup menarik minat murid. Oleh itu, penggunaan alat bantu mengajar yang lebih interaktif dan inovatif diperlukan bagi mengatasi masalah ini. Realiti maya (VR) sebagai alat bantu mengajar menawarkan satu pendekatan yang lebih interaktif dan menarik dalam pendidikan abad ke-21. Teknologi VR memberikan pengalaman pembelajaran yang bersifat imersif, di mana murid dapat berinteraksi dengan kandungan pelajaran dalam persekitaran maya yang menyerupai dunia sebenar.

1.2 Latar Belakang Kajian

Kajian ini dijalankan di Sekolah Kebangsaan Kota Masai 3, yang terletak di Pasir Gudang, Johor. Sekolah ini mempunyai bilangan murid yang pelbagai latar belakang, termasuk mereka

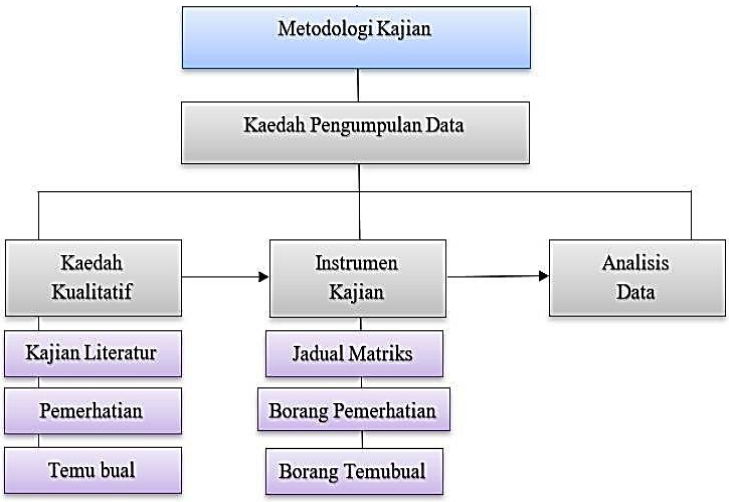
yang menghadapi kesukaran dalam penguasaan kemahiran membaca, khususnya dalam pengenalan huruf vokal dalam subjek Bahasa Melayu. Berdasarkan data daripada pihak sekolah, terdapat 34 murid yang mengikuti kelas pemulihan kerana kelewatan mereka dalam penguasaan literasi asas. Sekolah ini, seperti banyak sekolah lain, telah melaksanakan pelbagai program pemulihan dan intervensi untuk membantu murid-murid yang menghadapi cabaran dalam penguasaan kemahiran membaca. Walau bagaimanapun, walaupun beberapa usaha telah dilakukan, masih terdapat kekurangan dalam pencapaian literasi asas di kalangan sebahagian besar murid Tahun 1, terutamanya dalam penguasaan huruf vokal yang menjadi asas utama dalam pembelajaran membaca.

1.3 Pernyataan Masalah

Pelbagai inisiatif telah diperkenalkan oleh pihak kerajaan dan institusi pendidikan untuk memperkukuh penguasaan kemahiran asas membaca dalam kalangan murid sekolah rendah. Namun, cabaran masih wujud apabila ramai murid Tahun 1 masih belum menguasai kemahiran asas ini. Antara punca utama ialah kurangnya motivasi dan minat terhadap pembelajaran, yang mengakibatkan murid tidak memberi tumpuan sewajarnya di dalam kelas (Abdullah & Ismail, 2020). Keadaan ini turut berkait rapat dengan pendekatan pengajaran yang tidak efektif atau terlalu konvensional sehingga menyebabkan murid berasa bosan untuk belajar (Zainuddin et al., 2024). Tambahan pula, ketiadaan alat bantu mengajar (ABM) yang kreatif dan interaktif menjadi antara faktor yang menyukarkan murid untuk memahami konsep asas dengan lebih mendalam (Zainal & Karim, 2020). Dari sudut psikologi, tekanan dalaman seperti ketakutan terhadap kegagalan dan kurangnya keyakinan diri turut menjejaskan keupayaan murid untuk mengembangkan potensi mereka (Shah et al., 2021). Keadaan persekitaran pembelajaran yang kurang kondusif seperti kelas yang sempit dan bising juga boleh mengganggu tumpuan serta memberi kesan terhadap pencapaian akademik (Ahmad & Rahim, 2020).

2.0 METODOLOGI

Metodologi kajian adalah pelan tindakan yang menentukan bagaimana kajian akan dijalankan, bagaimana data akan dikumpul, dan bagaimana data tersebut akan dianalisis untuk menghasilkan kesimpulan yang sah dan relevan.



Rajah 1: Metodologi Kajian

Berdasarkan Rajah 1, kajian ini menggunakan pendekatan kaedah kualitatif yang melibatkan tiga kaedah pengumpulan data iaitu kajian literatur, temu bual, dan pemerhatian. Data yang

diperoleh akan dianalisis untuk melihat kesan penggunaan realiti maya (VR) interaktif oleh guru sebagai alat bantu mengajar terhadap penguasaan kemahiran membaca murid.

2.2 Pemerhatian

Pemerhatian telah dijalankan di dalam kelas Pemulihan Khas yang melibatkan seramai 18 orang murid dan 2 orang guru di Sekolah Kebangsaan Kota Masai 3, Pasir Gudang, Johor. Pengkaji menjalankan pemerhatian dengan mengamati proses pengajaran dan pembelajaran di dalam kelas, terutamanya apabila guru menggunakan realiti maya sebagai alat bantu mengajar huruf vokal. Pengkaji mencatat interaksi antara guru dan murid, serta tindak balas murid terhadap penggunaan teknologi ini. Selain itu, pengkaji juga memerhatikan kaedah pengajaran yang digunakan, suasana pembelajaran, dan tahap penglibatan murid dalam aktiviti yang dijalankan. Data pemerhatian ini akan dianalisis untuk menilai keberkesanan penggunaan realiti maya dalam meningkatkan pemahaman murid terhadap topik huruf vokal.

2.3 Temu bual Tidak Berstruktur

Temu bual tidak berstruktur turut dilaksanakan bersama 2 orang guru pemulihan bagi mendapatkan maklum balas secara terbuka mengenai pengalaman mereka dalam menggunakan alat bantu mengajar ini, termasuk potensi penggunaan teknologi VR dalam pengajaran. Temu bual ini memberi tumpuan kepada pendapat guru dalam aspek keberkesanan, cabaran, dan cadangan penambahbaikan dalam penggunaan bahan interaktif sebagai alat bantu mengajar bagi murid yang mempunyai kelemahan dalam kemahiran asas membaca.

2.4 Sampel dan Populasi Kajian

Populasi dalam kajian merujuk kepada kumpulan keseluruhan elemen atau individu yang menjadi fokus penyelidikan, di mana data akan dikumpulkan dan dianalisis. Manakala, sampel adalah subset atau sekumpulan kecil daripada populasi yang dipilih untuk mewakili keseluruhan populasi dalam kajian tersebut. Dalam kajian ini, sampel yang dipilih terdiri daripada murid dan guru yang terlibat secara langsung dalam penggunaan teknologi VR dalam pembelajaran.

Jadual 1: Sampel Kajian

	Populasi/ Sampel	Bilangan	Lokasi	Keterangan
1	Guru Pemulihan	2 orang	SK Kota Masai 3	Guru yang memberi pandangan mengenai penggunaan VR dalam pengajaran
2	Murid Pemulihan	18 orang	SK Kota Masai 3 , 2 Topaz	18 murid yang diuji dalam kajian penggunaan VR

Berdasarkan Jadual 1, sampel dalam kajian ini terdiri daripada 2 orang guru pemulihan dan 18 orang murid pemulihan. Kajian dijalankan di Sekolah Kebangsaan Kota Masai 3 kelas 2 Topaz. Guru-guru pemulihan bertanggungjawab memberi pandangan mengenai penggunaan realiti maya (VR) dalam pengajaran, sementara 18 murid diuji untuk menilai kesan penggunaan VR dalam proses pembelajaran mereka. Guru dan murid ini dipilih sebagai sampel untuk memahami bagaimana VR mempengaruhi pengajaran dan pembelajaran dalam kalangan murid pemulihan.

3.0 PERBINCANGAN

Hasil kajian ini menunjukkan bahawa penggunaan Realiti Maya (VR) dalam pengajaran huruf vokal bagi murid pemulihan yang menghadapi kesukaran membaca memberikan kesan yang positif terhadap penglibatan dan pemahaman mereka. Sebelum penggunaan VR, murid- murid ini menunjukkan minat yang rendah dalam proses pembelajaran huruf vokal melalui kaedah konvensional yang lebih berpusatkan guru.

Rajah 2: Sesi pengajaran bersama guru

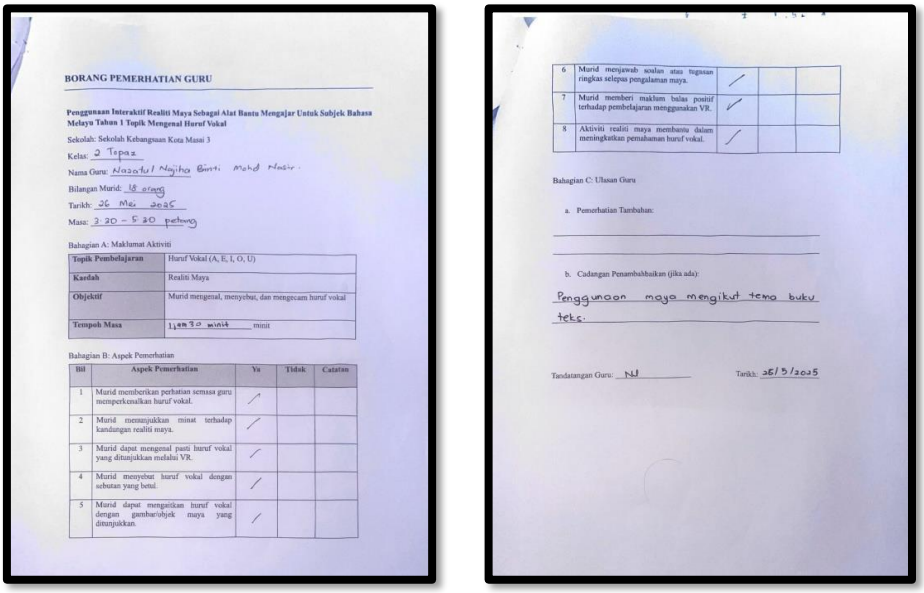
Berdasarkan Rajah 2, semasa sesi guru mengajar murid menggunakan VR utuk topik huruf vokal, murid terlihat lebih berminat untuk belajar dan mendengar arahan guru dengan baik. Guru berpuas hati dengan hasil keterlibatan murid yang sebelum ini pendiam dan selepas penggunaan VR, murid menjadi lebih aktif belajar.

Rajah 3: Hasil aktiviti murid semasa penggunaan VR

Berdasarkan Rajah 3, huruf vokal diwakili dengan objek yang berkaitan, seperti huruf "I" yang diwakili oleh objek ikan, yang membolehkan murid berinteraksi dengan objek tersebut dalam persekitaran maya. Elemen ini membolehkan murid mengenali bentuk dan bunyi huruf dengan lebih jelas. Selain itu, persekitaran maya yang imersif memberi peluang kepada murid untuk berinteraksi secara aktif dengan objek, menjadikan pembelajaran lebih menarik dan berkesan. Penggunaan elemen audio yang menyertakan bunyi huruf vokal juga membantu murid dalam mengenali hubungan antara bentuk huruf dan bunyinya. Gabungan elemen- elemen ini menjadikan pengajaran huruf vokal lebih menyeronokkan, meningkatkan penglibatan murid dan memudahkan mereka memahami konsep dengan lebih baik berbanding kaedah pengajaran tradisional.

Rajah 4: Penglibatan murid semasa penggunaan VR

Berdasarkan Rajah 4, selepas pengkaji melakukan pemerhatian di dalam kelas, pengkaji melihat peningkatan dalam penglibatan murid. Murid menjadi lebih aktif dan berminat untuk belajar, terutama ketika mereka dapat berinteraksi dengan objek dalam persekitaran maya. Mereka lebih fokus dan mudah memahami hubungan antara bentuk dan bunyi huruf vokal. Menurut kajian oleh Radianti et al. (2020) menekankan bahawa VR memberikan platform pembelajaran yang lebih menyeronokkan dan berkesan.



BORANG PEMERHATIAN GURU

Penggunaan Interaktif Realiti Maya Sebagai Alat Bantu Mengajar Untuk Subjek Bahasa Melayu Tahun 1 Topik Mengenal Huruf Vokal

Sekolah: Sekolah Kebangsaan Kota Masai 3

Kelas: 2 Topaz

Nama Guru: Nazatul Najiha Binti Mohd Nasir

Bilangan Murid: 18 orang

Tarikh: 26 Mei 2025

Masa: 3.20 – 5.20 petang

Bahagian A: Maklumat Aktiviti

Topik Pembelajaran	Huruf Vokal (A, E, I, O, U)
Kaedah	Realiti Maya
Objektif	Murid mengenal, menyebut, dan mengecam huruf vokal
Tempoh Masa	1 jam 30 minit ___ minit

Bahagian B: Aspek Pemerhatian

Bil	Aspek Pemerhatian	Ya	Tidak	Catatan
1	Murid memberikan perhatian semasa guru memperkenalkan huruf vokal.	✓		
2	Murid menunjukkan minat terhadap kandungan realiti maya.	✓		
3	Murid dapat mengenal pasti huruf vokal yang ditunjukkan melalui VR.	✓		
4	Murid menyebut huruf vokal dengan sebutan yang betul.	✓		
5	Murid dapat mengaitkan huruf vokal dengan gambar/objek maya yang ditunjukkan.	✓		
6	Murid menjawab soalan atau tugasan ringkas selepas pengalaman maya.	✓		
7	Murid memberi maklum balas positif terhadap pembelajaran menggunakan VR.	✓		
8	Aktiviti realiti maya membantu dalam meningkatkan pemahaman huruf vokal.	✓		

Bahagian C: Ulasan Guru

a. Pemerhatian Tambahan:

b. Cadangan Penambahbaikan (jika ada):

Penggunaan maya mengikut tema buku teks.

Tandatangan Guru: NJ Tarikh: 26/5/2025

Rajah 5: Borang Pemerhatian

Berdasarkan Rajah 5, dapatan kajian menunjukkan bahawa penggunaan VR meningkatkan tumpuan murid, memberi mereka peluang untuk belajar secara aktif dan meningkatkan pemahaman terhadap hubungan antara bentuk dan bunyi huruf vokal. Guru dan murid beri maklum balas positif terhadap pembelajaran berasaskan VR. Walau bagaimanapun, guru memberi cadangan penambahbaikan seperti tema di dalam VR lebih baik jika mengikut tema buku teks. Secara keseluruhannya, peningkatan minat murid ini terbukti apabila mereka lebih terlibat dalam setiap aktiviti yang melibatkan teknologi VR berbanding dengan aktiviti tradisional yang kurang interaktif. Selari dengan Teori Pembelajaran Multimedia oleh Mayer (2009), yang menekankan bahawa penggabungan pelbagai saluran pembelajaran (visual, auditori, kinestetik) dapat meningkatkan pemahaman dan pengingatan murid terhadap bahan pembelajaran.

4.0 KESIMPULAN

Kajian ini membuktikan bahawa kaedah interaktif berasaskan realiti maya berpotensi menjadi pendekatan yang berkesan dan menarik dalam pengajaran huruf vokal Bahasa Melayu kepada murid pemulihan, sekali gus meningkatkan penglibatan, pemahaman dan pencapaian mereka dalam pembelajaran asas membaca. VR menyediakan persekitaran pembelajaran yang interaktif, yang membantu murid untuk lebih fokus dan memahami konsep dengan lebih baik. Implikasi praktikal untuk guru adalah bahawa VR boleh menjadi alat bantu mengajar yang berkesan untuk memperbaiki penguasaan literasi awal. Penggunaan VR memberi peluang kepada guru untuk melaksanakan kaedah pengajaran yang lebih inovatif dan menarik, sekali gus meningkatkan keberkesanan pembelajaran di kalangan murid.

Cadangan kajian lanjut adalah untuk menilai kesan jangka panjang penggunaan VR dalam meningkatkan penguasaan kemahiran membaca, khususnya dalam kalangan murid- murid yang mempunyai kesulitan pembelajaran. Kajian lanjutan juga boleh diteruskan untuk melihat bagaimana teknologi VR dapat digunakan dalam subjek lain selain Bahasa Melayu, seperti Matematik dan Sains, untuk membantu murid memahami konsep yang lebih kompleks. Selain itu, kajian ini boleh diteruskan dengan melibatkan lebih banyak sekolah dan murid dari latar belakang yang berbeza untuk melihat sejauh mana keberkesanan VR dalam konteks yang lebih luas.

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Projection Mapping as A Promotional Medium for Cultural Awareness for Batik Johor

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ABSTRACT

This study explores the potential of projection mapping as an innovative promotional tool to enhance cultural awareness and appreciation for Batik Johor. With traditional batik facing competition from mass-produced textiles, there is an urgent need to reposition it in the minds of younger generations through modern digital platforms. By utilizing projection mapping a technique that transforms irregular surfaces into dynamic video displays this research highlights how projection mapping can effectively communicate the cultural value and heritage embedded in Batik Johor. A mixed-methods approach was adopted, involving interviews with local artisans, visual designers, and cultural experts, as well as a pilot projection mapping installation. Results demonstrate that projection mapping significantly improves audience engagement and understanding of Batik Johor's unique motifs and history.

Keywords: projection mapping, batik johor, cultural heritage, visual communication, digital promotion

1.0 INTRODUCTION

1.1 Batik Johor

Originating in the southern Malaysian state of Johor, Batik Johor is a distinctive textile art form known for fusing traditional Malay motifs with modern design elements. In a rapidly modernising society, Batik Johor finds it difficult to remain relevant despite its deep cultural significance. Digital media has emerged as a crucial instrument for promoting culture, and projector mapping is notable for its ability to use motion graphics to engage audiences in public areas. This study investigates the potential of projection mapping as a tool for promoting and revitalising Batik Johor, especially with younger and tech-savvy audiences.

1.2 Projection Mapping

In the field of preservation, projection mapping is still largely unknown and novel. In addition to general and technical procedures and applications in the field of historic preservation, this section looks at its theory and history. A deeper understanding of these projection mapping characteristics will reveal hitherto unreported features of the technology and offer a foundation for its practical implementation. Numerous events and performances demonstrate the widespread use of projection mapping in the entertainment industry. Both industry and medicine are using this strategy.

1.3 Projection Mapping in Cultural Communication

The ability of projection mapping to spread and reinterpret cultural narratives is highlighted in a number of studies. Artists have used this medium in the context of public art and heritage to depict myths, oral histories, and traditional motifs on sites that hold cultural significance (Nunes & Green, 2020). The "Badu Gili" projection at the Sydney Opera House, which uses animations to project onto the building's sails to honour First Nations stories, is a prime

example. This program has received praise for showcasing indigenous art in a contemporary and widely available manner (González & Kuri, 2021). Comparably, Japan's NAKED, Inc. projections and Lyon's "Light Festival" have combined digital art with local culture to encourage travel and intergenerational communication (Ito & Yamamoto, 2022).

1.4 Educational and Participatory Potentials

Additionally, projection mapping has been used in educational settings to provide interactive instruction on cultural heritage. Tschacher et al. (2021) observe that by enabling visitors to dynamically examine historical artefacts and architectural reconstructions, projection installations in museums can promote deeper cognitive engagement. According to Huang et al. (2020), participatory approaches improve authenticity and democratise cultural narratives by allowing local communities to contribute stories, images, or performances. In addition, public exhibitions and festivals have reclaimed communal spaces for cultural expression through the use of projection mapping.

1.5 Problem Statement

Renowned for its unique designs and deep cultural origins, Johor batik is an important part of the state's history. However, it is clearly becoming less prevalent in modern society. This decline is largely caused by a lack of design innovation, a lack of promotional efforts, and little interaction with younger generations. Effective awareness-raising tactics are clearly lacking, which has led to a decline in market competitiveness and a decline in the value of this cultural asset. These worries are echoed in scholarly commentary. For example, traditional textiles like Batik Johor are in serious danger of becoming marginalised unless proactive and creative steps are taken to raise their profile in contemporary cultural and economic contexts, according to Kamaruddin et al. (2017). According to Abdullah, Mohd. Yusof, and Abdul Aziz (2020), traditional crafts like batik are unable to compete both domestically and abroad due to a lack of digital engagement and antiquated marketing strategies. Batik Johor is in real danger of becoming obsolete without significant reform and revitalisation; this loss would go beyond business to include cultural identity.

2.0 METHODOLOGY

Through textual analysis, this study uses qualitative research methods to look at relevant case studies and literature. In cultural heritage contexts, textual analysis is a legitimate research to ol that allows for the investigation of complexity in a digital narrative environment and facilitates comprehension of how these narrative elements improve visitor interaction and educational opportunities. In order to enhance Batik Johor, the study created and evaluated a projection mapping prototype utilizing the ADDIE instructional design methodology. The five stages of the ADDIE model analysis, design, development, implementation, and evaluation are widely applied in instructional technology design (Molenda, 2021; Kurt, 2018).

2.1 Analysis

The study determined the instructional, audience, and particular learning objectives of the projection mapping application throughout the analysis phase. Research was done to comprehend the visual aesthetics, setting, and motifs of Batik Johor. Along with determining technical nee ds like projector specifications and space arrangements for optimal display, this phase also included analyzing the potential impact of projection mapping as a medium for improving public involvement with conventional performing arts.

2.2 Design

Conceptualising the motion and visual components for the projection mapping presentation will be the main goal of the design phase. The goal of this step was to create a motion graphics that would highlight Batik Johor in the projection. Special attention was paid to coordinating visual effects with the traditional themes of Batik Johor in order to maximise audience engagement and preserve cultural accuracy. Technical preparation during this phase included creating graphical content, choosing mapping software (Adobe After Effects), and coordinating the visual and aural elements to create an immersive experience.

2.3 Development

Using the design specifications, the prototype was created during the development stage. Digital content, including animations, pictures, and audio, was produced as part of this using Batik Johor elements. By using specialised projection mapping software to project the content onto real surfaces, the ideal display environment was replicated. To ensure that the data matched the surface's textures and shapes, the photos were continuously tested. During this iterative phase, technical problems had to be found and changes had to be made in light of early testing.

2.4 Implementation

In the Implementation phase, the prototype was tested in a controlled setting where users could interact with the immersive display and projection mapping. For the best possible visual clarity and engagement, the setup included ambient adjustments and projector calibration.

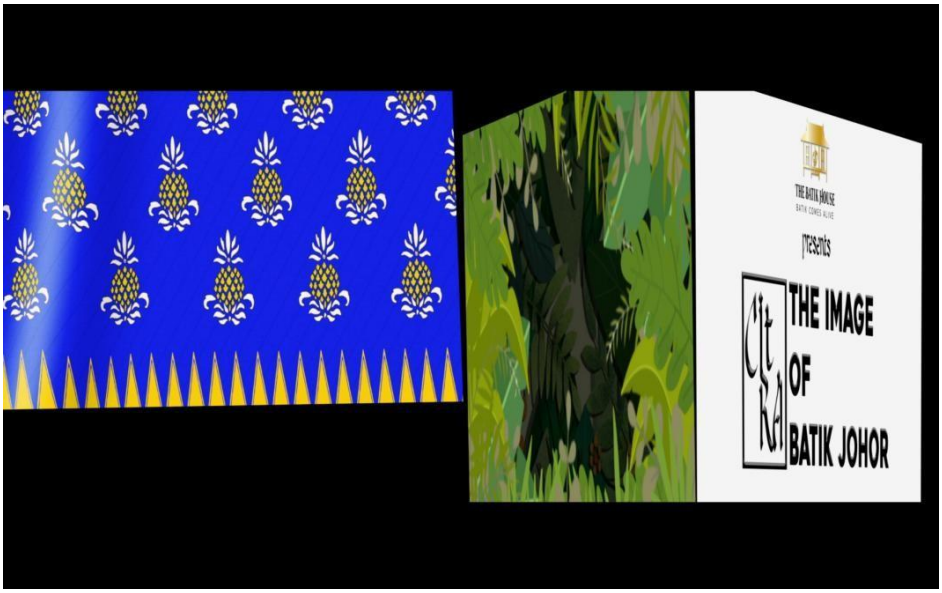

Figure 1- Mapping Surfaces

To identify the primary types of interactions that occur in these selected texts, data analysis will employ Ryan's (2006) interactive narrative framework. This study will investigate how various interaction types internal, external, ontological, and exploratory affect visitor engagement and educational outcomes. The findings will be compared across internal-ontological, external-ontological, internal-exploratory, and internal-exploratory interaction types in order to find similarities and differences in PM. This approach aims to provide insight into the best practices in PM integration within the framework of cultural tourism in order to ensure better visitor experiences and cultural awareness.

2.5 Evaluation

The prototype's effectiveness in presenting the *Batik Johor* motifs motion was evaluated via feedback sessions and surveys during the final phase. Audience input was obtained to assess how projection mapping affects knowledge of *Batik Johor* motifs. Analysis of responses revealed strengths and areas for improvement in projection mapping as a tool for cultural awareness. Quantitative feedback analysis validated design decisions and paved the way for future advancements.

3.0 RESULTS AND DISCUSSION

Projection mapping's capacity to transform public spaces into cultural canvases serves as a compelling approach to engage both local communities and tourists. Through animated visual sequences, Batik Johor motifs are no longer static decorative elements but active agents of storytelling. This transformation aligns with Tschacher et al. (2021), who argue that interactive and immersive media formats contribute to stronger cultural retention and identity reinforcement. The evaluation form using Likert scale **1 : Strongly Disagree**, **2 : Disagree**, **3 : Neutra**l, **4 : Agree** and **5 : Strongly Agree.**

3.1 Aesthetic Appeal of Motion Graphics

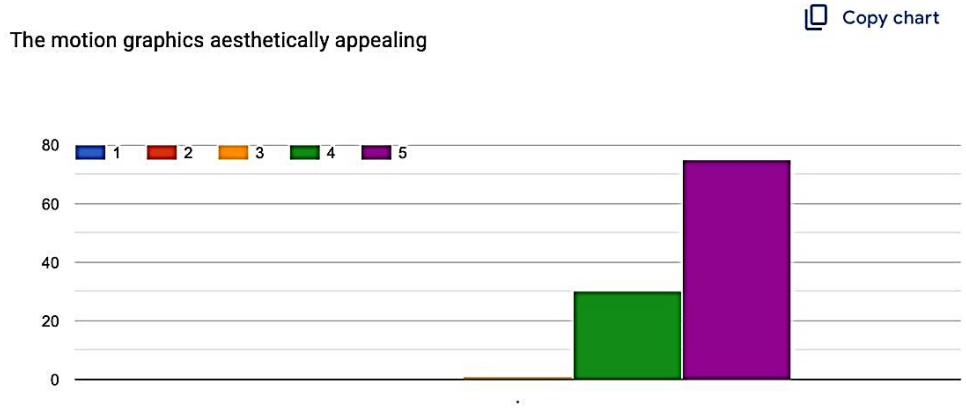

Figure 2- Questionnaire Results

The first question assessed whether the motion graphics were aesthetically appealing. The majority of respondents rated this aspect highly, with 75% assigning a score Strongly agree, and approximately 25% for agree. This overwhelmingly positive feedback indicates that the visual elements, including motif integration and background music, were perceived as visually pleasing and professionally executed.

3.2 Cultural Message Conveyed through Projection Mapping

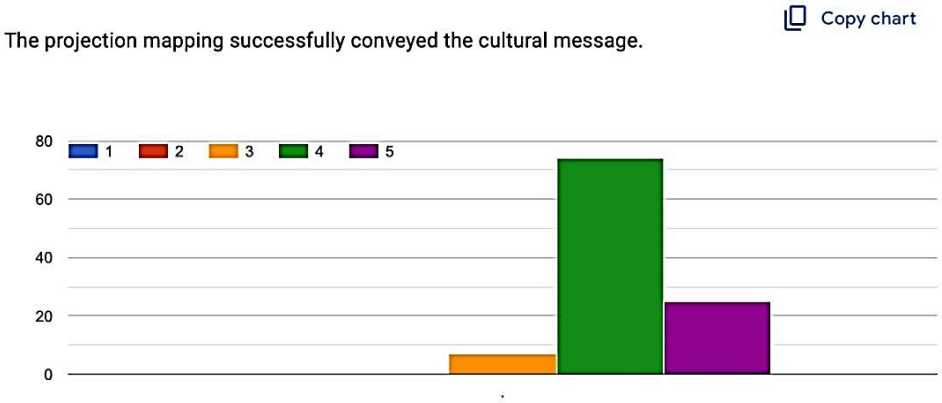

Figure 3- Questionnaire Results

In the second evaluation item, participants rated the effectiveness of projection mapping in conveying cultural messages. A substantial majority (around 70%) rated it a 4: Agree, with a smaller yet significant portion (approximately 25%) assigning for Strongly Agree. These results suggest that the projection mapping technique was successful in delivering the intended cultural narrative to the audience, albeit with minor room for improvement to reach full effectiveness.

3.3 Clarity of Batik Motifs and Pattern

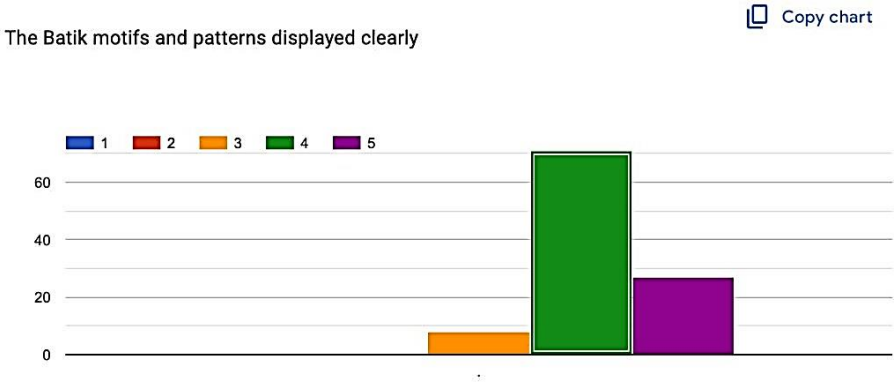

Figure 4- Questionnaire Results

The third aspect evaluated was the clarity of Batik motifs and patterns within the motion graphics. Results were similar to the previous question, with approximately 65% of respondents choose strongly and around 30% providing a rating of agree This indicates that the majority of viewers were able to clearly identify and appreciate the traditional Batik motifs, affirming the successful visual communication of the design.

4.0 CONCLUSION

Projection mapping represents a powerful digital tool for promoting cultural heritage, offering a compelling way to present Batik Johor in contemporary visual language. The research supports the idea that combining art, technology, and culture can enhance public appreciation and stimulate cultural pride. Moreover, this strategy not only preserves tradition but

recontextualizes it in modern environments, fostering intergenerational dialogue. As Malaysia pushes forward in its digital transformation agenda, incorporating such multimedia tools into cultural preservation efforts could become a best practice for heritage communication.

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Promotional Video as Ecoproduct Campaign of Perniagaan Benang Serat Nanas M&Z

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ABSTRACT

This study explores the development of a promotional documentary video for Perniagaan Benang Serat Nanas M&Z, a traditional business in Pontian, Johor, specializing in the production of pineapple fiber yarn. The enterprise faces the challenge of limited public awareness and insufficient marketing strategies, which restrict its ability to reach a broader audience and promote its eco-friendly products. To address this, the video was designed to visually narrate the transformation of pineapple leaves into fine yarn, while also emphasizing the preservation of cultural heritage and sustainable practices unique to the business. The methodology adopted was qualitative, involving in-depth interviews with the business owner, direct observations of the production process, and a review of relevant literature to inform the documentary's content and structure. Data collected from interviews and observations were systematically analyzed to ensure the video authentically represented the business and effectively communicated its values. The study's analysis focused on how well the documentary engaged viewers and conveyed the intended messages about sustainability and craftsmanship. Findings indicate that the video successfully increased viewers' understanding and appreciation of eco-friendly crafts, enhanced the business's visibility. In conclusion, this study demonstrates that a thoughtfully produced promotional documentary video can significantly contribute to raising awareness, educating audiences, and supporting the growth of traditional, sustainable enterprises.

Keywords: promotional video, documentary video, pineapple fiber, eco-product campaign.

1.0 INTRODUCTION

The selection of this project focuses on creating a promotional documentary video for Perniagaan Benang Serat Nanas M&Z, a traditional Pontian, Johor-based company that uses sustainable, manual methods to make eco-friendly pineapple fiber yarn. The purpose of this initiative is to help nearby eco-entrepreneurs use efficient marketing and write better business plans, mainly those promoting environmental sustainability and the heritage of the culture. As more people care about sustainable and artisanal products, the call for true stories and clear pictures to illustrate their worth and uniqueness is increasing everywhere. So popular are promotional videos and docuseries now because they teach, put local goods ahead, promote cultural values and attract visitors (Kaur et al., 2023). Thanks to social media and digital technology, marketing content is now more important and effective which allows traditional and small businesses to reach more people and contribute to their communities (Rahman et al., 2022).

1.2 Perniagaan Benang Serat Nanas M&Z

Eco-products from a community or region contain materials from nature, are biodegradable and use processes that focus on protecting the environment. In Malaysia, many people who prefer eco-friendly living are choosing bamboo utensils, beeswax wraps, reusable bags, organic soaps, and items that don't create waste (according to ShopUnplug, 2022). They assist in maintaining the earth's balance and help carry forward local heritage by saving

theenvironment and regional objects. Anyone who establishes and manages a company focused on the environment is called an ecopreneur. They come up with ideas for products and services that make the environment safer, use fewer resources and support buying environmentally friendly items. By joining care for nature with business success, they do a lot for the green economy, commonly help local communities, and promote sustainability. Rising awareness among consumers and new rules from the government are causing ecopreneurship to increase in Malaysia (Majcafe, 2022). In Malaysia, the small business Benang Serat Nanas M&Z makes pineapple fiber yarn using agricultural leftovers which is good for the environment. Because it uses traditional ways, caring for the environment and cultural heritage, this business demonstrates ecopreneurship by changing natural pineapple leaves into sustainable yarn. Selling its unique product and energy-saving program, the company still lacks marketing exposure. This project addresses these matters by making a promotional documentary film.

1.3 The drawbacks of lacking a promotional digital product.

Many environmentally conscious businesses in the area, such as Perniagaan Benang Serat Nanas M&Z, use traditional marketing strategies that have helped them grow in the past; however, these approaches could be improved further to better penetrate today's dynamic market and cultural landscape. As interest in sustainability and authenticity grows and digital marketing methods improve, small firms may find it more difficult to express the unique value of their eco-friendly products and extend their consumer base through traditional advertising. By incorporating more contemporary promotional tools, such as documentary films that highlight their unique processes and positive environmental impact, these businesses can better engage modern consumers, strengthen brand recognition, and gain a competitive advantage in the evolving eco-product sector (Ahmad et al., 2021).

Showcasing the efforts of Perniagaan Benang Serat Nanas M&Z in making their craft, preserving the environment, and upholding their culture is one of the research goals of the project. This aspect also focuses on figuring out how using visuals boosts the awareness of a brand and makes customers more involved. The investigation is based on research asking how a promotional video can further spread Perniagaan Benang Serat Nanas M&Z's eco-friendly products to more potential customers. It also investigates which methods of documentary tell stories in a way that broadens the audience and shares the brand's involvement in cultural and sustainable matters. The study plans to point out how digital media can help regions grow economically and environmentally and it will also contribute to research in academics and marketing for small eco-enterprises.

2.0 METHODOLOGY

The method for creating the promotional documentary video follows a three-phase multimedia production framework that includes pre-production, production, and post- production. This approach ensures that the video is planned, executed, and refined in a systematic manner while remaining consistent with the project's goals of fostering eco- entrepreneurship and cultural preservation. The process, founded on qualitative research and user-centered design principles, combines stakeholder input, creative narrative, and iterative feedback to create an engaging and powerful end product (Rabiger & Hurbis-Cherrier, 2020).

2.1 Post-production

The pre-production stage, where all the planning and preparation happen before filming, is

vital for multimedia projects to succeed. To begin the pre-production phase, I studied the Nanas M&Z business by observing and speaking with its employees and the company's owner. At this point, we could find out what marketing issues the company faced, what values were important to the business and how its unique pineapple fiber yarn was produced. All the information gathered was put together in a storyboard and script that explained the main ideas, story structure and how everything would appear on screen. At this stage, it was important to define how the creative would match the company's principles and what the target audience would like to see (Rabiger & Hurbis-Cherrier, 2020). Before filming started, logistical planning was done by making a list of shots, picking filming dates and obtaining the necessary permits for filming outside. For effective manufacturing, the team planned the equipment they needed, organized all necessary transport, and kept in communication with participants. There were very few disruptions thanks to the good advance planning and resources and time were used efficiently. Before filming, it was important to survey the risks and plan for any emergencies that might occur during production (Millerson & Owens, 2012). With pre-production finished, the team managed to set up all the details and strategies for the next stages.

2.2 Production

This stage consisted of recording the documentary which meant turning the plans and storyboards into real scenes. They took excellent pictures at every step of turning pineapple leaves into fibers and using them to weave yarn. The camera team focussed on detailed shots of the artisans' dexterity and the crafting tools of their time, as these are essential parts of what the business is known for. The crew recorded interviews with important figures such as the founder and employees, so the viewer could understand what gave the company its values and the ways people work together to make a difference. By combining process photos with the interviews, an insightful and engaging movie was created. As production proceeded, the team adapted well to any new changes that appeared. Different camera angles, lighting and sound were used to guarantee that each scene was done perfectly and realistically. The filmmakers also used B-roll to add images of nature, raw goods used and the finished products to give the audience more details and a better picture. While the storyboard and shot list from pre-production helped plan the filming, the team allowed for any unusual moments that could make the movie more engaging. Everyone followed coronavirus safety rules and the environment was comfortable for everyone to ensure things went smoothly on the set (Rabiger & Hurbis-Cherrier, 2020).

2.3 Post-production

Post-production marks the crucial phase where raw footage is carefully transformed into a cohesive documentary. At this point, editors meticulously review all material, selecting the strongest takes and arranging sequences to align with the initial storyboard. This process weaves together interviews, B-roll, and process shots to create a unified narrative. To enhance engagement and narrative clarity, elements such as graphics, background music, and voiceovers are incorporated. Attention is paid to technical details color correction ensures visual consistency, sound mixing balances audio elements, and subtitles are added to improve accessibility and comprehension. These refinements collectively elevate the documentary's aesthetic and professional quality. Throughout post-production, the team collaborates closely with stakeholders, gathering feedback and making necessary adjustments. This iterative process ensures the final product authentically represents the brand and achieves the intended goals of the project (Dancyger, 2018).

Upon completion, the video was exported in multiple formats to accommodate distribution across various platforms, such as social media channels and YouTube. Subsequent evaluation relied on audience feedback and engagement metrics to determine whether the documentary effectively stimulated interest in, and awareness of, the company's environmentally sustainable products. The post-production phase involved careful refinement of the documentary's messaging to optimize its value as both a marketing and educational resource. Beyond technical and aesthetic considerations, the iterative review process ensured that the final product resonated with the intended audience and contributed meaningfully to broader goals, including the promotion of eco-entrepreneurship and the preservation of cultural heritage (Millerson & Owens, 2012).

Table 1: Production Process of Promotional Documentary Video

Stage	Key Activities
Pre-Production	Research Interviews Observation Scriptwriting, Storyboarding Scheduling
Production	Filming Capturing B-roll Lighting Sound recording
Post-Production	Editing Voiceover, Music Graphics, Color correction Sound mixing, Subtitles Final review

3.0 RESULTS AND DISCUSSION

The project culminated in a curated series of promotional documentary videos that illuminate the eco-friendly production methods, deep-rooted cultural heritage, and sustainable entrepreneurship of Perniagaan Benang Serat Nanas M&Z. The principal aim of this video series was to foster public awareness concerning the merits of pineapple fiber products, illustrating both their environmental advantages and the meticulous manual craftsmanship inherent to each item. By amplifying the brand's profile within a highly competitive marketplace, the series sought to position Perniagaan Benang Serat Nanas M&Z as an innovator in sustainable practices. Each episode was deliberately organized to explore distinct facets of the business, guaranteeing comprehensive content and an engaging viewing experience for a broad spectrum of audiences.

The opening series of the series functions as a foundational introduction to the company, its founder, and the overarching mission guiding its operations. Viewers are acquainted with the origins of Perniagaan Benang Serat Nanas M&Z, based in Pontian, Johor, and the motivations that propelled the transformation of pineapple leaf waste into sustainable yarn. Drawing upon interviews with the founder and archival materials, the episode sheds light on the initial challenges encountered during the company's formative period, as well as the enduring commitment to environmental sustainability. The narrative adopts an inviting tone, fostering

a personal connection between the audience and the brand. Ultimately, this episode establishes a framework for the forthcoming series, underscoring the significance of eco-entrepreneurship and the preservation of cultural heritage.

The second video offers a detailed exploration of the pineapple fiber yarn production process, beginning with the harvesting of pineapple leaves and proceeding through fiber extraction, cleaning, spinning, and ultimately, weaving the yarn. Through the use of close-up shots and slow-motion footage, the video effectively highlights the complexity and precision of the manual techniques, as well as the traditional tools utilized by the artisans. Interviews with workers provide valuable perspectives regarding their expertise, daily practices, and the sense of pride they derive from their craft. This episode serves to educate viewers on the labor-intensive nature of sustainable, eco-friendly textile production and underscores the environmental advantages of repurposing agricultural waste. In doing so, it clearly demonstrates the company's dedication to sustainable practices.

The third series presents an in-depth examination of the diverse range of products crafted from pineapple fiber yarn, encompassing textiles, artisanal handicrafts, and contemporary fashion accessories. Through first-hand accounts from both customers and residents, the episode illustrates the tangible benefits arising from the business's operations within the community. Moreover, the narrative extends to analyze the broader socioeconomic impact of Perniagaan Benang Serat Nanas M&Z, particularly in relation to local economic development, employment opportunities, and the revitalization of traditional craftsmanship among younger generations. Visual storytelling techniques are employed to showcase not only the aesthetic qualities and adaptability of the finished products but also the enterprise's significant contribution to fostering communal pride and supporting sustainable livelihoods.

The final video in the series addresses the challenges faced by the business, such as limited marketing resources and competition from mass-produced goods. It also discusses the company's vision for the future, including plans to expand its reach through digital marketing and collaborations with eco-conscious partners. The episode concludes with a call to action, encouraging viewers to support local eco-entrepreneurs and make sustainable choices. Through candid interviews and reflective narration, this episode underscores the resilience and adaptability of Perniagaan Benang Serat Nanas M&Z and its ongoing commitment to environmental stewardship and cultural preservation

Series 1 Background of Perniagaan Benang Serat Nanas M&Z	Series 2 Planting and Harvesting Process

Series 3 Process of getting yarn from pineapple leaves	Series 4 Thread connecting process

Figure 1 The series of promotional documentary video

3.1 Study Finding

Based on the questionnaire results, it was found that the documentary helped make both the products and the company more visible and of greater value. Looking at qualitative data such as viewers' comments and interviews, it became clear that the audience learned about the traditional production of pineapple fiber yarn and the good impact of recycling agricultural waste on the environment. People from various countries were impressed by the way the documentary showcased the company's special factors such as its manual craftsmanship, history, and commitment to the environment. Thanks to visual storytelling, the brand name became more familiar and relevant, and it helped close the gaps between the company and possible clients. It also pointed out that user-centered design played a major role in how the documentary was made. Content was adjusted to the preferences and goals of the audience by letting them take part in its development. According to what I learned from YouTube comments and polls, viewers liked how real the documentary was and now look more favorably at pineapple fiber eco-products. It also became clear from the outcomes how much an informative documentary can teach the public about both the product and the main themes. Enhanced social media participation and many additional questions about the company and its goods helped to show this rise in interest. All in all, the research showed that small eco-firms such as Perniagaan Benang Serat Nanas M&Z can use documentary videos to market themselves effectively. It was found that when digital platforms are used, great designs in visuals can help a brand go further than simple marketing methods. The study shows that local firms with similar goods can do well in tough markets, strengthen their local identity and support sustainability in the area by applying multimedia storytelling to their marketing. To sum up, the project met its goals and became a model for future efforts in advertising eco-products.

Table 2 Demographic Information Table

Category	Subcategory	Percentage of Respondents	Insight
Age Group	19 below	10.4%	
	20–25	43.3%	Majority are aged 20–25
	26–30	19.4%	
	30 and above	26.9%	
Gender	Male	41.8%	
	Female	58.2%	Females are the predominant respondents.
Race	Malay	41.8%	
	Chinese	53.7%	Chinese respondents form the largest group.

	Indian	4.5%	
Education Level	SPM	61.2%	Majority of respondents have SPM qualifications.
	Diploma	6%	Very few hold a Diploma.
	Degree	28.4%	Second most common education level.
	Masters/PhD	4.4%*	Minimal advanced degree holders.
Occupation	Student	25.4%	1 in 4 respondents are students.
	Employed	6%	Low representation of traditionally employed individuals.
	Self-Employed	67.2%	Dominant occupation category.
	Not Employed	1.4%*	Negligible unemployment among respondents.

Table 3 Awareness, Engagement, Feedbacks from the questionnaire

Topic	Metric	Response	Percentage	Key Insight
Topic 3: Awareness	Heard/Used Pineapple Fiber Products	Yes	22.4%	Low awareness; only ~1/5 familiar with products.
		No	7.5%	Minimal outright lack of awareness.
		Not Sure	**70.1%**	**Critical gap**: Majority uncertain, highlighting need for education.
Topic 4: Engagement	Attention Maintenance	Yes (Engaged)	**98.5%**	Documentary held near-universal attention.
		No/Maybe	1.5%	Negligible drop in engagement.
	Overall Engagement	Very Engaging	**79.1%**	Over 3/4 found it highly compelling.
		Somewhat Engaging	13.4%	
		Neutral	9%	
	Favorite Part	Series 3	**59.7%**	Most impactful segment.
		Series 2	52.2%	
		Series 1	49.3%	
		Series 4	47.8%	
	Inspired Interest?	Yes	**100%**	All respondents motivated to explore eco-friendly options.
Topic 5: Feedback	Suggested Improvements	Storyline	26.9%	Top area for refinement.
		Editing	23.9%	Second priority for improvement.
		Video Approach	11.9%	Lesser concern.

	Content	9%	
	No Improvement Needed	28.3%	Over 1/4 saw no flaws.
Overall Rating (1–5)	5 (Very Effective)	**61.2%**	Strong positive reception.
	4	28.4%	
	3	7.5%	
	1–2	3%	Minimal negative feedback.
Recommendation Likelihood	Yes	**100%**	Unive

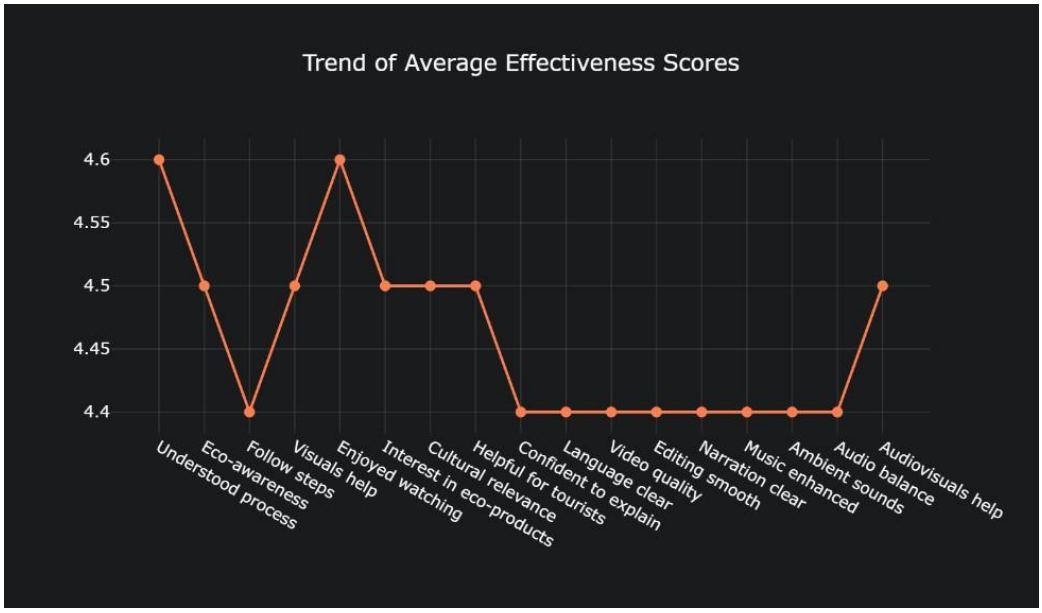

Figure 1 Chart of Overall Findings of the Questionnaire

CONCLUSION

On the basis of the research, it has been found that using digital storytelling and promoting documentaries can deal with the challenges of Perniagaan Benang Serat Nanas M&Z. As a result of the documentary video, more people were made aware of pineapple fiber products and learned about their benefits. YouTube comments prove that visual stories can inspire people, create favorable thoughts and lead to interest in handicrafts.

The project met its objectives, identified useful solutions, made a promotional video and looked at the video's impact by reacting to the audience's feedback. This project benefits marketing research and supports environmentally friendly ways of doing business and it can be used as an example by other small businesses using digital media to grow. Using documentaries for marketing creates excellent opportunities for both supporting eco-entrepreneurship and saving Malaysia's cultural heritage.

ACKNOWLEDGEMENT

The influence of the community and the Perniagaan Benang Serat Nanas M&Z enterprise cannot be ignored as they gave this research and creativity a real foundation. Because the business was open about their ways of working and hopes, it became possible to accurately document their techniques and save their cultural traditions. By observing how pineapple leaf waste is turned into yarn, the project team learned more and emphasized the key role of sustainable entrepreneurship in Malaysia's rural areas. Participation in this project has demonstrated that academic research teaming up with community efforts is valuable for addressing today's marketing and environment problems.

The work aligns with the educational mission of the department which asks students to combine educational models and hands-on projects that serve their own communities. Because of the necessary research, design and review, the promotion video turned out both attractive and informative for use in both business and learning. The project proves that visual storytelling encourages eco-friendly choices and supports local businesses, so future actions can use this approach to support sustainability and culture.

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Simulasi Penggunaan Kad Imbas Suku Kata Berasaskan Realiti Maya (VR) Bagi Murid Tahun Satu Pemulihan Literasi

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ABSTRAK

Kemahiran asas membaca merupakan komponen terpenting dalam penguasaan literasi awal murid tahun satu. Namun, masih terdapat sebahagian murid yang gagal menguasai kemahiran ini meskipun telah mengikuti sesi pembelajaran secara formal. Isu kelemahan dalam mengenal pasti suku kata menjadi antara punca utama murid tidak dapat membaca dengan lancar, sekali gus menjejaskan prestasi akademik mereka. Justeru, kajian ini dijalankan untuk menilai penggunaan kad imbas suku kata berasaskan teknologi Realiti Maya (VR) sebagai alat bantu mengajar (ABM) inovatif bagi murid tahun satu yang tidak menguasai kemahiran asas membaca. Kajian ini menggunakan pendekatan kualitatif secara pemerhatian dan temu bual. Seramai 10 orang murid tahun satu dan dua orang guru literasi turut terlibat dalam proses penilaian bagi pengajaran menggunakan simulasi Kad Imbas Suku Kata. Hasil kajian menunjukkan tarikan dan respons positif murid, keberkesanan penyampaian dalam pembelajaran, pengalaman baharu dan pendedahan teknologi kepada guru dan potensi VR sebagai alat bantu mengajar masa hadapan secara lebih meluas dalam ABM bagi mata pelajaran Bahasa Melayu. Kesimpulannya, penggunaan Kad Imbas Suku Kata berasaskan teknologi VR sebagai ABM dilihat berpotensi besar dalam membantu murid yang mempunyai masalah membaca, khususnya dalam aspek penguasaan suku kata. Kajian ini mencadangkan integrasi teknologi (VR) secara lebih meluas dalam pengajaran awal literasi pada masa akan datang.

Kata kunci: alat bantu mengajar, kad imbas, literasi awal, realiti maya, suku kata.

1.0 PENGENALAN

1.1 Pendahuluan

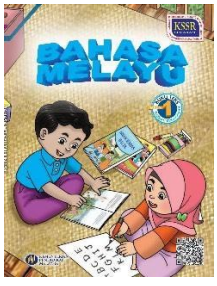
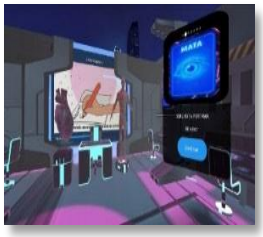
Kemahiran asas membaca merupakan elemen utama dalam sistem pendidikan awal kerana ia menjadi asas kepada semua aspek pembelajaran yang lebih kompleks. Di Malaysia, isu kemahiran asas membaca terus menjadi cabaran, bagi murid di peringkat tahun satu. Menurut laporan Kementerian Pendidikan Malaysia (KPM), sebanyak 27.5% murid tahun satu pada tahun 2024 gagal menguasai kemahiran asas literasi, yang melibatkan seramai 122,000 murid (Fadhlina, 2024). Terdapat beberapa komponen penting yang menyumbang kepada kelemahan murid dalam penguasaan literasi. Antaranya adalah kaedah pengajaran tradisional kurang menarik dan menyebabkan murid cepat bosan. (Ahmad & Zainuddin, 2021) Malah menurut Nazrul,2021) lagi ketiadaan alat bantu mengajar (ABM) yang efektif menyukarkan murid memahami pelajaran, memaksa mereka bergantung sepenuhnya kepada guru, dan kehilangan keyakinan diri. Dari aspek sikap murid apa yang dapat dikatakan adalah mereka cepat berputus asa, hilang keyakinan diri, dan tidak berminat untuk belajar, yang telah menyebabkan kemerosotan dalam pencapaian akademik. Semua ini berpunca dari sikap mereka yang cepat berputus asa (Tamam Timbang, Zamri Mahamod, Afendi Hamat, 2021). Akhir sekali, masalah psikologi seperti kurang keyakinan diri atau ketakutan gagal menjadikan murid tertekan, menghindari perkara baru, serta berisiko mengalami kecemasan atau kemurungan ringan (Dayang Julida Abang Tar, Muhd Izwan Mahmud, 2021). Semua faktor ini saling berkaitan dan mempunyai kesan langsung ke atas pencapaian murid dalam penguasaan kemahiran asas

literasi. Salah satu usaha yang dilaksanakan oleh kerajaan dalam menangani isu murid yang belum menguasai kemahiran asas membaca ialah dengan mewujudkan Kelas Pemulihan Khas di sekolah rendah. Inisiatif ini bertujuan untuk memberi tumpuan khusus kepada murid yang menghadapi kesukaran dalam literasi, melalui pendekatan pengajaran yang lebih bersifat individual, sistematik dan mesra murid (Kementerian Pendidikan Malaysia, 2013) dengan melihat pengaruh teknologi digital dewasa ini, penggunaaan realiti maya turut mendapat perhatian.

Realiti Maya ialah teknologi simulasi yang mencipta persekitaran maya yang membolehkan interaksi imersif dengan persekitaran atau objek 3D menggunakan peranti khusus seperti *headset* VR (Burdea & Coiffet 2003). Penggunaan Realiti Maya (Virtual Reality, VR) sebagai Alat Bantu Mengajar (ABM) dalam pengajaran dan pembelajaran semakin mendapat perhatian dalam dunia pendidikan moden. Teknologi ini membolehkan guru dan murid berinteraksi dalam persekitaran simulasi tiga dimensi yang imersif dan realistik (Radianti et al., 2020). Melalui VR, murid dapat mengalami situasi pembelajaran secara langsung dan lebih menarik, sekaligus meningkatkan tumpuan, motivasi, dan pemahaman mereka terhadap sesuatu topik (Freina & Ott, 2015). Bagi guru, VR memberi peluang untuk menyampaikan kandungan pelajaran dengan lebih kreatif dan berkesan. Di samping itu, penggunaan VR juga menyokong pelbagai gaya pembelajaran murid, terutamanya pembelajaran secara visual dan kinestetik (Makransky & Lilleholt, 2018). Justeru, VR sebagai ABM tidak mustahil untuk memainkan peranan yang besar dalam memperkayakan pengalaman pembelajaran dan menjadikan proses pengajaran lebih interaktif dan bermakna bagi murid pemulihan literasi dalam Bahasa Melayu.

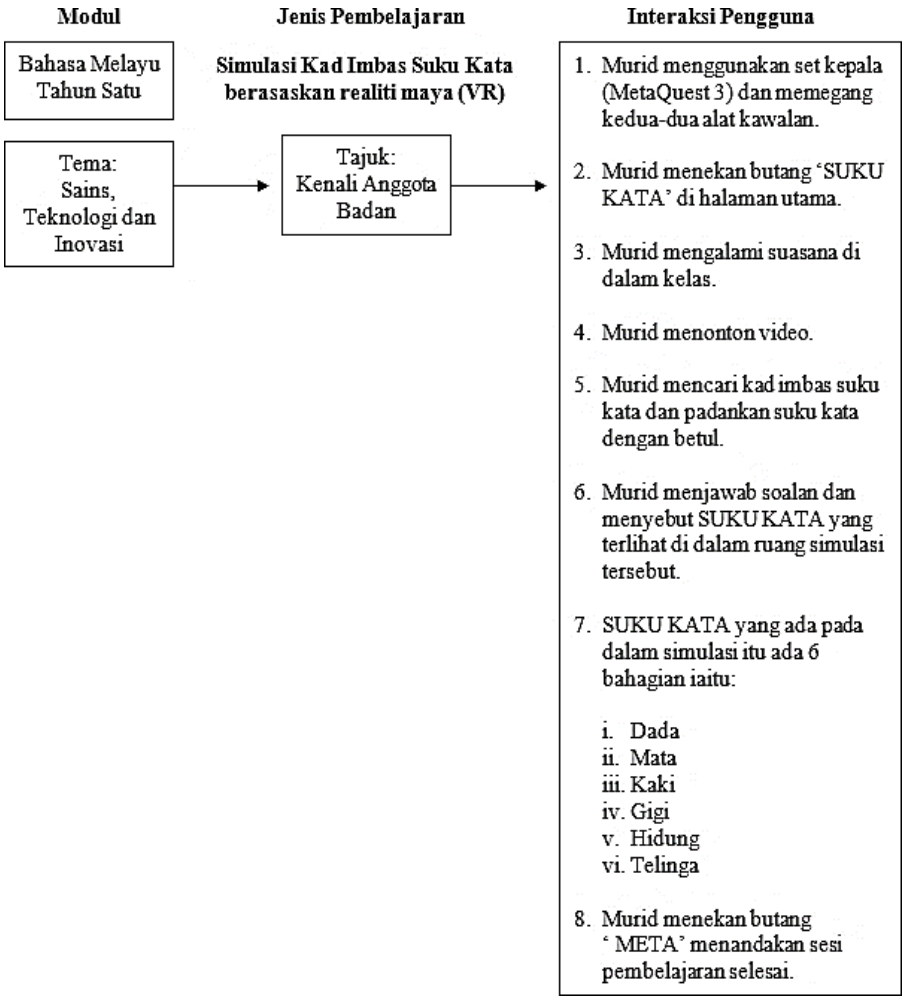
2.0 METODOLOGI

Kajian ini menggunakan pendekatan metodologi kualitatif dengan kaedah pemerhatian dan temu bual bagi mendapatkan maklumat secara mendalam berkaitan penggunaan alat bantu mengajar menggunakan Kad Imbas Suku Kata berasaskan Realiti Maya (VR) yang dibangunkan. Kad Imbas Suku Kata ini dibangunkan menggunakan modul yang telah ditetapkan oleh guru pakar Bahasa Melayu yang terlibat. Merujuk kepada Rajah 2, modul yang digunakan dalam kajian ini berasaskan Buku Teks Bahasa Melayu Tahun Satu di bawah tema Sains, Teknologi dan Inovasi. Jenis pembelajaran yang diaplikasikan adalah simulasi menggunakan Kad Imbas Suku Kata secara realiti maya (VR) yang bertajuk "Kenali Anggota Badan".

			
Modul	Murid memakai set kepala (Meta Quest 3)	Murid berada di dalam ruang Simulasi	Murid menyebut suku kata yang diberikan

Rajah 1: Kad Imbas Suku Kata

Dari sudut interaksi pengguna, murid menggunakan peranti set kepala Meta Quest 3 serta memegang kedua-dua alat kawalan tangan. Pada permulaan sesi, murid akan menekan butang SUKU KATA' di halaman utama simulasi, lalu dibawa ke suasana maya menyerupai bilik darjah. Dalam ruang simulasi ini, murid akan menonton video pengenalan berkaitan anggota badan. Seterusnya, murid dikehendaki mencari kad imbas suku kata dan memadankan suku kata tersebut dengan betul berdasarkan bahagian anggota badan yang dipelajari. Murid turut menjawab soalan serta menyebut suku kata yang dipaparkan dalam ruang simulasi sebagai latihan pertuturan dan pengukuhan kosa kata. Terdapat enam bahagian anggota badan yang di fokuskan dalam simulasi ini iaitu, Dada, Mata, Kaki, Gigi, Hidung, dan Telinga. Setelah selesai aktiviti pembelajaran, murid akan menekan butang 'META' sebagai penanda bahawa sesi pembelajaran telah tamat. Kaedah ini menggabungkan elemen visual, audio dan interaksi fizikal untuk meningkatkan tumpuan serta pemahaman murid dalam pembelajaran asas Bahasa Melayu melalui pendekatan teknologi imersif. Sesi pengajaran dan pembelajaran berlaku selama satu jam tiga puluh minit.



Rajah 2: Model Konsep Simulasi Kad Imbas Suku Kata berasaskan realiti maya (VR)

Pemerhatian dijalankan terhadap guru dan murid semasa sesi pengajaran dan pembelajaran menggunakan simulasi Kad Imbas Suku Kata berasaskan VR bagi menilai interaksi, penglibatan, dan tindak balas mereka sepanjang aktiviti berlangsung. Seterusnya, temu bual

dilaksanakan bersama dua orang guru yang dipilih sebagai responden bagi mendapatkan pandangan, pengalaman, serta maklum balas mereka terhadap keberkesanan dan kesesuaian penggunaan Kad Imbas Suku Kata berasaskan VR sebagai alat bantu mengajar. Sekolah Kebangsaan Kota Masai 3, yang terletak di Pasir Gudang, Johor merupakan lokasi kajian dijalankan. Daripada jumlah populasi seramai 34 orang murid yang mengikuti kelas pemulihan tidak menguasai kemahiran asas literasi (membaca). Pengkaji hanya memilih 10 orang murid sebagai sample kajian dan dua orang guru yang terlibat merupakan guru yang telah ditentukan oleh pihak sekolah berdasarkan kepada kepakaran dalam kelas pemulihan Bahasa Melayu dan mengajar Bahasa Melayu bagi sampel murid yang terlibat di dalam kajian ini. Seramai 10 orang murid Tahun Satu Topaz merupakan salah satu kumpulan murid yang mengikuti kelas pemulihan literasi terlibat dalam sesi simulasi ini untuk menilai impak penggunaan Kad Imbas Suku Kata berasaskan VR terhadap pengalaman pembelajaran mereka.

Sesi pemerhatian telah dijalankan semasa proses pengajaran dan pembelajaran di dalam kelas yang melibatkan penggunaan Simulasi Kad Imbas Suku Kata berasaskan realiti maya (VR) bagi murid tahun satu pemulihan literasi. Pemerhatian ini dijalankan secara langsung di dalam kelas bagi menilai penggunaan Simulasi Kad Imbas Suku Kata berasaskan teknologi Realiti Maya (VR) sebagai alat bantu mengajar (ABM) inovatif bagi murid tahun satu yang tidak menguasai kemahiran asas membaca. Dapatan daripada pemerhatian ini membantu pengkaji mendapatkan gambaran keseluruhan tentang sejauh mana penggunaan Simulasi Kad Imbas Suku Kata berasaskan realiti maya (VR) sebagai alat bantu mengajar (ABM) inovatif bagi murid tahun satu yang tidak menguasai kemahiran asas membaca. Manakala sesi tembual tidak berstruktur telah dijalankan bersama dengan dua orang guru literasi yang terlibat dalam proses penilaian bagi pengajaran menggunakan simulasi Kad Imbas Suku Kata bagi mendapatkan pandangan untuk sebarang penambahbaikan pada masa akan datang.

3.0 HASIL KAJIAN DAN PERBINCANGAN

Hasil dapatan berdasarkan pemerhatian terhadap guru dan murid semasa aktiviti simulasi penggunaan Kad Imbas Suku Kata berasaskan teknologi Realiti Maya (VR) menunjukkan tahap interaksi dan penglibatan yang tinggi dalam kalangan murid. Penggunaan teknologi realiti maya (VR) yang digunakan dalam Simulasi Kad Imbas Suku Kata mesra pengguna dan mudah dikendalikan oleh murid dengan bimbingan guru. Peranti set kepala (MetaQuest 3) berjaya menarik minat murid dan memberikan pengalaman pembelajaran yang berbeza dan menyeronokkan (AlAli & Wardat, 2024).. Dari segi aspek tingkah laku mendapati bahawa murid menunjukkan perubahan tingkah laku yang positif semasa menggunakan Kad Imbas Suku Kata berasaskan relaiti maya (VR). Mereka dilihat lebih fokus, mudah faham dan berani mencuba membaca suku kata secara kendiri. Murid juga menunjukkan tahap keterlibatan yang tinggi serta mengulang sebutan dan memberi kerjasama dengan rakan semasa aktiviti dilaksanakan. Ini menujukkan bahawa pendekatan ini berkesan dalam merangsang penglibatan aktif murid yang sebelum ini pasif di dalam kelas. Murid dilihat lebih fokus, teruja dan aktif memberi respons sepanjang sesi berlangsung. Mereka menunjukkan minat yang mendalam terhadap elemen visual dan persekitaran maya yang ditawarkan melalui teknologi VR, yang secara tidak langsung meningkatkan motivasi mereka untuk belajar dan mencuba membaca suku kata. Bagi aspek pengaruh visual pula, elemen visual dalam simulasi memainkan peranan penting dalam menarik perhatian murid. Penggunaan konsep Sains fiksyen *(Sci-fI)*, video, avatar (seperti anggota badan) membantu meningkatkan daya tumpuan dan pemahaman murid (Sourced Study, 2023). Kandungan Kad Imbas Suku Kata dalam simulasi direka bentuk dengan jelas dan sesuai tahap kognitif murid tahun satu, input sampai kepada murid Suku Kata yang

dipaparkan mudah dikenali, serta menggunakan tulisan dan warna yang bereuaian mengikut konsep yang diberikan. Interaktiviti yang disediakan, seperti suara panduan dan animasi video turut meningkatkan kefahaman murid terhadap perkataan yang diperkenalkan, terbukti berkesan.

Dari aspek pemerhatian terhadap guru, mendapati mereka berperanan sebagai fasilitator yang membimbing murid secara lebih fleksibel dan kreatif. Guru juga menunjukkan kesediaan dan keterbukaan dalam meneroka kaedah pengajaran baharu, di samping memberikan maklum balas positif terhadap keberkesanan VR sebagai alat bantu mengajar. Tindak balas guru dan murid secara keseluruhannya menunjukkan bahawa penggunaan VR mampu mewujudkan suasana pembelajaran yang menyeronokkan, interaktif dan bermakna, sekali gus membantu dalam penguasaan kemahiran asas membaca khususnya dalam aspek pengenalan dan pembacaan suku kata. Hasil dari pemerhatian mendapati bahawa respons guru sangat memberangsangkan kerana ini merupakan teknologi baru yang diguna pakai guru melaporkan bahawa penggunaan Simulasi Kad Imbas Suku Kata (VR) bukan sahaja membantu dalam menarik minat murid malah penggunaan Simulasi Kad Imbas Suku Kata berasaskan realiti maya (VR) ini mampu membuatkan murid memberikan tumpuan minat murid untuk terus melakukan pembelajaran sehingga selesai.

a.Taklimat oleh pengkaji	b. Persediaan guru	c. Persediaan murid
a.Interaksi	b. Penglibatan	c. Tindak balas

Rajah 3: Hasil Pemerhatian Simulasi

Manakala melalui temubual bersama guru berkaitan refleksi keseluruhan simulasi penggunaan Kad Imbas Suku Kata berasaskan VR berdasarkan pandangan guru A dan guru B sebagai peserta kajian:

> *Cikgu A menyatakan bahawa dengan penggunaan Kad Imbas Suku Kata berasaskan VR ini dapat menjadikan proses pengajaran lebih interaktif, menyeronokkan dan sesuai untuk murid yang mempunyai tahap fokus rendah. Dengan kemampuan yang ditunjukkan dalam penggunaan teknologi ini secara keseluruhannya juga berkesan dari aspek penglibatan murid dan keberkesanan pengajaran, malah turut memberi pendedahan teknologi yang bermanfaat kepada guru dan murid dalam usaha memperkukuh literasi awal.*

Cikgu B turut berpandangan bahawa penggunaan Kad Imbas Suku Kata berasaskan VR ialah penggunaan kaedah pengajaran dan pembelajaran yang baru, murid juga teruja apabila mereka menggunakan Kad Imbas Suku Kata VR. Selain itu, murid ingin nak mencuba serta murid cepat kuasai pembelajaran dengan Menggunakan kaedah pembelajaran ini. Sangat terbaik.

Rajah 4: Temu bual bersama guru literasi

Segala pandangan yang dilontarkan oleh dua orang guru dalam kajian ini jelas menyokong kepada kajian yang telah dilakukan oleh Muhamad Nazrul, Muhammad Helmi, dan Noorhayati (2021) yang menjelaskan kepada kita kepentingan digital era dalam dunia pendidikan seperti permainan digital, AR dan penggunaan *head-mounted display*. Namun begitu penggunaan teknologi VR ini ada pro dan kontranya. Perkara ini jelas melalui hasil kajian mengenai Keberkesanan Penggunaan Realiti Maya dalam Kurikulum Pendidikan Malaysia, yang merangkumi empat aspek utama iaitu kelebihan teknologi VR, kelemahan teknologi VR, peluang penggunaan teknologi VR dan ancaman teknologi VR dalam sistem pendidikan. Kelebihan teknologi VR dapat membantu murid mengeksplorasi situasi atau tempat yang mustahil dalam realiti. Manakala kelemahan teknologi VR jelas menunjukkan kebanyakan aplikasi dalam teknologi ini masih berada pada peringkat prototaip dan belum sedia untuk kegunaan umum. Namun tidak dapat dinafikan peluang penggunaan teknologi VR menunjukkan pengintegrasian teknologi ini dalam pengajaran dan pembelajaran menggambarkan masa depan yang cerah, selaras dengan gaya hidup generasi Z dan risiko yang tinggi apabila kita hanya berpegang atau menggunakan hanya satu platform teknologi, cabaran dalam menjamin kelestarian penggunaan teknologi VR pada masa hadapan boleh menjadi satu bentuk ancaman terhadap penerapannya dalam sistem pendidikan.

4.0 KESIMPULAN

Kajian ini menunjukkan bahawa penggunaan Kad Imbas Suku Kata berasaskan teknologi Realiti Maya (VR) sebagai alat bantu mengajar (ABM) mampu memberikan impak positif terhadap penguasaan kemahiran membaca dalam kalangan murid Tahun Satu. Masalah kelemahan dalam mengenal suku kata merupakan antara punca utama murid gagal membaca dengan lancar, sekali gus menjejaskan prestasi akademik mereka. Penggunaan kaedah tradisional yang kurang menarik menyebabkan murid mudah hilang tumpuan dan tidak berminat untuk belajar. Oleh itu, pendekatan pembelajaran yang lebih interaktif dan inovatif amat diperlukan. Melalui pendekatan kualitatif yang melibatkan pemerhatian dan temu bual,

didapati bahawa penggunaan VR mampu menarik minat murid dan meningkatkan penglibatan mereka secara aktif dalam sesi pembelajaran. Guru turut mengakui keberkesanan kaedah ini dalam menyampaikan pengajaran dengan lebih jelas dan berkesan. Selain memberikan pengalaman pembelajaran yang menyeronokkan kepada murid, teknologi (VR) juga memberi pendedahan baharu kepada guru dalam usaha memperkasa pendekatan pengajaran berasaskan teknologi. Secara keseluruhannya, penggunaan Kad Imbas Suku Kata berasaskan (VR) sebagai ABM dilihat berpotensi besar dalam membantu murid yang menghadapi kesukaran membaca, khususnya dalam aspek penguasaan suku kata. Kajian ini mencadangkan agar integrasi teknologi seperti realiti maya (VR) diperluas penggunaannya dalam pengajaran awal literasi Bahasa Melayu. Pendekatan ini bukan sahaja selari dengan kehendak pendidikan abad ke-21.

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The Development of Imarazak Website of New Promotion Strategy

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ABSTRACT

The development of the official website for The Batik House by Imarazak is essential in promoting the brand as a significant cultural and e-commerce destination in Johor Bahru, offering a rich experience in traditional batik heritage. Although general information can be accessed through official platforms like Imarazak's website, the details are often limited and infrequently updated, which poses challenges in user satisfaction and the effectiveness of cultural promotion. This study aims to develop and evaluate the effectiveness of The Batik House by Imarazak's website as a promotional tool by improving information delivery and promotional strategies through a user-friendly and regularly updated platform. A mixed- method approach was employed, incorporating design thinking techniques. To complete the design process, the researcher gathered feedback from 65 respondents, including owner craft staff, and the general public. Findings indicate high user satisfaction with the updated website's user interface (UI), averaging a score of 4.71, user experience (UX) at 4.65, and awareness at 4.20. Specifically, 69% of respondents strongly agreed with the well-organized layout, 67% with its smooth functionality, and 97% expressed increased confidence and interest in visiting the physical boutique, indicating strong overall satisfaction. This research highlights the importance of an effective website in promoting The Batik House by Imarazak. The newly developed site has proven to be a successful promotional tool, enhancing user experience and increasing public awareness. Recommendations include continuously updating the website content and integrating more interactive features.

Keywords: Batik, E-commerce, Website development, User experience (UX), User interface (UI), Promotion

1.0 INTRODUCTION

In support of Malaysia's ongoing digital transformation agenda, the National Tourism Policy 2020 – 2030, introduced by former Prime Minister Tan Sri Muhyiddin Yassin, underscores the critical role of digitalization in strengthening the tourism sector. This includes empowering local creative industries and cultural enterprises through the development of effective digital platforms. In this context, the official website for The Batik House by Imarazak serves as a strategic promotional tool that not only highlights Malaysia's rich batik heritage but also supports broader goals of educational and cultural tourism in Johor. While national platforms such as Kraftangan Malaysia provide basic listings of craft locations, they are often static and not regularly updated, limiting their reach and impact (Salleh et al., 2020).

As a cultural brand rooted in traditional textile craftsmanship, Imarazak requires modern promotional strategies to reach both local and international audiences. A dynamic and user- friendly website plays a central role in digital branding, providing a centralized platform for storytelling, product showcasing, and visitor engagement (Chaffey & Ellis-Chadwick, 2019). Through integration of interactive content such as virtual showroom tours, video demonstrations, and real-time updates, the Imarazak website enhances user experience and builds emotional connection with the brand. According to Kotler et al. (2021), emotional branding and experiential content are essential for attracting culturally curious tourists and promoting artisanal products in the digital era.

This study focuses on the development and evaluation of the Imarazak website as a digital promotional strategy to increase brand visibility, user engagement, and public awareness of traditional batik culture. Using a mixed-method approach incorporating design thinking and structured user feedback, the research identifies key areas of enhancement in user interface (UI), user experience (UX), and digital storytelling. Findings demonstrate that a well-designed website can function as a powerful branding tool that complements offline promotional efforts, encourages edu-tourism, and supports sustainable cultural entrepreneurship in Johor.

2.0 METHODOLOGY

2.1 Research Method

This study employed a mixed-method research approach to develop and evaluate the effectiveness of the Imarazak official website as a promotional tool for cultural and craft-based tourism. The research adopted the Design Thinking framework, which includes five key phases: empathize, define, ideate, prototype, and test. In the empathize phase, the researcher conducted informal interviews and observations involving potential users such as batik customers, tourists, and local craft enthusiasts to understand their needs and digital behavior. In the ideation and prototyping stages, the website was designed with a focus on user experience (UX), user interface (UI), and content relevancy. To assess its effectiveness, a structured questionnaire was distributed to 65 respondents, including local visitors, educators, and cultural stakeholders, using a Likert-scale instrument to measure satisfaction levels in areas such as layout, navigation, content clarity, and promotional appeal. Quantitative data were analyzed using descriptive statistics to determine mean scores and user preferences, while qualitative feedback was used to identify areas for improvement. This methodological approach ensured that the website development was user-centered, data-driven, and aligned with the promotional goals of The Batik House by Imarazak.

2.2 Population and Research Sample

The target population for this study consisted of individuals who are directly or indirectly involved with cultural tourism, craft appreciation, and online shopping behavior. These include local visitors to Kompleks Kraf Johor, educators promoting cultural heritage, museum and craft center staff, and members of the general public with an interest in traditional batik. A purposive sampling method was employed to select 65 respondents who could provide relevant insights into user experience (UX), website usability, and promotional effectiveness. This non- probability sampling technique is appropriate when the researcher seeks participants with specific characteristics relevant to the research objective (Etikan, Musa, & Alkassim, 2016). The respondents were diverse in terms of age, background, and familiarity with digital platforms, ensuring a broad range of perspectives. Their feedback, collected through questionnaires and informal interviews, was used to evaluate the effectiveness of the Imarazak website in delivering cultural content, promoting batik products, and enhancing public engagement.

2.3 Research Instruments

The primary research instrument used in this study was a structured questionnaire designed to collect quantitative and qualitative data on user perceptions of the Imarazak website. The questionnaire was divided into several sections, including demographic information, user interface (UI) evaluation, user experience (UX), content relevance, website functionality, and promotional effectiveness. A five-point

Likert scale was utilized to measure the level of agreement for each item, ranging from "strongly disagree" (1) to "strongly agree" (5). This scale allows for standardized and interpretable data, suitable for analyzing trends in user satisfaction and usability (Joshi et al., 2015). In addition, open-ended questions were included to gather in-depth user feedback and suggestions for website improvement. The instrument was validated through expert review and a pilot test involving a small group of respondents to ensure clarity, reliability, and content validity. This approach ensured that the instrument was both user-focused and aligned with the research objectives in evaluating the website's role as a digital promotional tool.

2.4 Data Collection

Data collection for this study was conducted through the distribution of structured questionnaires both online and in-person to gather feedback from selected respondents on the usability and promotional effectiveness of the Imarazak website. The data collection process took place over a period of two weeks and involved 65 participants, including local visitors, educators, craft enthusiasts, and members of the general public with interest in cultural heritage and digital platforms. Online distribution was carried out via Google Forms, while physical copies were administered at Kompleks Kraf Johor to reach respondents who preferred face-to- face interaction. Respondents were briefed on the purpose of the study and their consent was obtained prior to participation, in line with ethical research practices. The use of both digital and manual methods ensured wider reach and better inclusivity, as suggested by Creswell & Poth (2018), who emphasized the importance of diverse data collection methods to enhance the reliability and richness of research findings. The collected data were then organized for analysis using descriptive statistics and thematic categorization for open-ended responses.

2.5 Data Analysis

The data collected from the structured questionnaires were analyzed using descriptive statistical methods to evaluate the effectiveness of the Imarazak website in terms of user interface (UI), user experience (UX), content relevance, and promotional value. Quantitative data from the Likert-scale responses were processed mean scores, frequency distributions, and percentage analyses, which provided clear insights into user satisfaction and website performance. Averages were used to identify strengths and weaknesses in key areas such as layout design, ease of navigation, and engagement level. Additionally, qualitative data from open-ended responses were analyzed using thematic analysis to extract recurring feedback, suggestions, and user concerns. This dual approach of quantitative and qualitative analysis enabled a more holistic evaluation of the website's impact and informed actionable improvements, aligning with the analytical strategies recommended by Miles, Huberman, & Saldaña (2014) for mixed-method research.

3.0 RESULT AND DISCUSSION

3.1 Empathize and Define

In the empathize phase, the researcher aimed to understand the needs, behaviors, and expectations of target users regarding their interaction with the Imarazak website. This was achieved through informal interviews, direct observation at Kompleks Kraf Johor, and preliminary surveys involving local visitors, educators, and craft enthusiasts. Insights gathered revealed that users desired a visually engaging platform, easy navigation, updated information, and features that reflect the uniqueness of traditional batik culture. These findings informed the define phase, where specific problem statements were formulated, such as "Users need a more interactive and visually appealing website to appreciate the cultural value of batik," and "Lack of timely updates reduces the site's effectiveness as a promotional tool." By clearly identifying these user-centered problems, the study was able to set focused design objectives aimed at improving user experience (UX), strengthening promotional strategies, and enhancing engagement with The Batik House by Imarazak. This process aligns with the principles of human-centered design, as emphasized by Brown (2009), which places user empathy at the core of digital solution development.

3.2 Ideate and Develop

In the ideate phase, the researcher generated multiple creative concepts for the design and structure of the Imarazak website based on user needs identified in the empathize and define phases. Brainstorming sessions and reference analysis of successful cultural and e-commerce websites were conducted to inspire layout ideas, color schemes, and interactive features that could enhance user engagement. Several initial sketches and wireframes were produced, focusing on key elements such as homepage structure, batik product display, and storytelling content to reflect Imarazak's cultural identity. Moving into the develop phase, the best ideas were translated into a working prototype using modern web development tools and responsive design principles. The website was developed with a focus on visual appeal, ease of use, and mobile compatibility to cater to a wider audience. Interactive features such as image sliders, embedded videos, and clickable product sections were implemented to create a dynamic and immersive user experience. This development process ensured that the website not only functioned effectively but also aligned with promotional and branding goals, as recommended by Lockwood (2010) in design-driven innovation practices.

3.3 Testing

In the testing phase, the developed Imarazak website prototype was evaluated through real user interaction to identify its effectiveness, usability, and areas for improvement. A group of 65 respondents consisting of educators, cultural visitors, and the general public were invited to explore the website and provide feedback using a structured questionnaire. The evaluation focused on aspects such as user interface (UI), user experience (UX), content clarity, navigation flow, and promotional appeal. Quantitative data collected via a Likert scale indicated high satisfaction, with mean scores above 4.5 for interface design and ease of use, while qualitative feedback highlighted strengths such as the modern layout, attractive visual elements, and clear cultural messaging. Minor usability issues, such as loading time and mobile responsiveness, were identified and addressed in the final iteration of the website. This iterative testing approach ensured that the final product was user-centered and aligned with the platform's promotional goals, consistent with best practices in user experience testing as described by Nielsen (2012).

Table 3.1 : Section in Questionaire

Section	Aspect	No. of Question
Section A	Demography	8
Section B	Awareness of Imarazak brand	3
Section C	Website Design and Visual Appeal	3
Section D	Brand Perception & Satisfaction	3
Section E	Perception of Current Promotional Strategy	3
Section F	Suggestions for New Promotion Strategy	2
Section G	Overall Opinion and Feedback	2

Table 3.2 : Demography

No.	Demography	Types	Frequency	Total%
1	Age	18 – 22	4	2.6
		23-24	14	9.1
		25	18	11.7
		26-51	19	12.35
		52	10	6.5
2	Gender	Male	29	18.85
		Female	36	23.4
3	Race	Malay	62	40.3
		India	3	1.95
		Chinese	0	0.0
4	Marital Status	Married	26	16.9
		Single	39	25.35
5	Education Level	O Level	9	5.85
		A Level	5	3.25
		Sijil	0	0.0
		Diploma	19	12.35
		Bachelors	30	19.5
		Master	1	0.65
		Phd	1	0.65
6	Occupation	Student	9	5.85
		Banker	11	7.15
		Housewife	2	1.3
		Lawyer	1	0.65
		Teacher	12	7.8
		Designer	10	6.5
		Others	20	13

3.3.1 User Interface

The user interface (UI) of the Imarazak website was designed to reflect both modern web aesthetics and the traditional essence of Malaysian batik culture. A clean, minimalist layout was adopted, complemented by a warm color palette inspired by natural batik dyes to evoke authenticity and cultural identity. Key UI elements such as clear navigation menus, responsive buttons, product thumbnails, and

interactive sliders were strategically placed to enhance visual clarity and encourage user engagement. Typography choices emphasized readability across devices, while consistent iconography guided users smoothly through the browsing experience.

The UI was developed with mobile-first responsiveness in mind to ensure seamless access on smartphones and tablets, catering to modern user behavior. This attention to design not only improved usability but also strengthened the brand image of The Batik House by Imarazak as a professional and culturally rooted platform. According to Garrett (2011), effective UI design is critical in shaping first impressions and influencing user trust — both of which are essential for promotional success in digital platforms.

Table 3.3 : Awareness of Imarazak Brand and Website Design and Visual Appeal

No	Question	Interpretation
1.	What type of platform did you prefer online shopping	High
2.	Have you heard of the *Imarazak* brand before this?	High
3.	How did you first learn about Imarazak?	High
4.	Have you visited the *Imarazak* website?	High
5.	The website layout is visually attractive.	High
6.	The color scheme and typography reflect the brand identity.	High
7.	The product images and graphics are professionally presented.	High
	Total	**High**

3.3.2 User Experience

The user experience (UX) of the Imarazak website was carefully crafted to ensure that visitors could interact with the platform in a seamless, enjoyable, and meaningful manner. From the moment users landed on the homepage, they were met with intuitive navigation, fast loading speeds, and culturally rich content that reflected the identity of The Batik House by Imarazak. Features such as product zoom-in, batik history sections, and interactive galleries allowed users to explore and connect emotionally with the traditional art of batik. According to survey results, users rated their overall experience highly, with an average mean score of 4.65, indicating satisfaction with ease of use, content relevance, and engagement level. Consistent with UX design principles by Krug (2014), the website emphasized clarity, minimal cognitive load, and accessibility across devices, which helped users complete their goals whether it was learning about batik or making a purchase—with minimal friction. The positive user experience not only enhanced the credibility of the platform but also increased user retention and likelihood of revisits.

Table 3.4 : Brand Perception & Satisfaction and Perception of Current Promotional Strategy

No	Question	Interpretation
1.	The website is easy to navigate.	High
2.	The loading speed of the website is acceptable.	High
3.	The product information is clear and informative.	High
4.	The website's current promotional content is engaging.	High
5.	Discounts, vouchers, or promotions are clearly shown.	High
6.	The promotions influence your decision to buy.	High
	Total	**High**

3.3.3 Awareness

The development of the Imarazak website significantly contributed to increasing public awareness of The Batik House by Imarazak as a local cultural brand that promotes traditional batik heritage. Prior to the website's launch, public exposure to the brand was limited to physical visits at Kompleks Kraf Johor and occasional social media posts. With the website in place, users were able to access comprehensive information about the brand's history, batik collections, cultural values, and purchasing options anytime and anywhere. The digital platform served as a centralized and updated promotional tool, helping to expand reach beyond Johor to national and even international audiences. Based on survey findings, 97% of respondents reported increased awareness of the brand and expressed greater interest in visiting or purchasing batik products. This supports the idea that a well-designed and informative website plays a crucial role in enhancing brand visibility and consumer engagement (Kotler, Bowen, & Makens, 2016). The improved accessibility and storytelling approach of the Imarazak website successfully positioned it as a digital ambassador for promoting Malaysian batik culture.

Table 3.5 : Suggestions for New Promotion Strategy and Overall Opinion and Feedback

No.	Question	Interpretation
1.	Which promotion strategies would attract to you buy from the Imarazak website?	High
2.	What other platforms do you think Imarazak can apply use more for promotions into?	High
3.	Overall, how satisfied are you with the Imarazak website?	High
	Total	**High**

3.4 Discussion

The findings of this study indicate that the development of the Imarazak website successfully addressed key user needs in terms of accessibility, content delivery, and promotional impact. High satisfaction scores in user interface (mean = 4.71) and user experience (mean = 4.65) demonstrate that users found the website visually appealing, easy to navigate, and engaging. Moreover, the significant increase in awareness (mean = 4.20) among respondents highlights the website's effectiveness as a digital marketing tool in promoting traditional batik culture. These outcomes align with previous research suggesting that well-designed cultural websites can improve brand reach and visitor engagement (Kotler et al., 2016; Garrett, 2011). The integration of multimedia elements such as image sliders and virtual galleries further enriched the online experience, supporting theories of immersive content increasing user involvement (Krug, 2014). The use of design thinking throughout the development process ensured that user feedback was consistently incorporated, resulting in a platform that met both functional and promotional goals. This project confirms that digital platforms are essential for sustaining cultural heritage brands in the digital age, particularly in niche markets like artisanal batik.

Feedback collected from users during the testing phase of the Imarazak website played a crucial role in validating the design and identifying areas for improvement. A total of 65 respondents, including educators, cultural enthusiasts, and the general public, participated in a structured survey that assessed key elements such as user interface, content clarity, navigational ease, and overall satisfaction. The responses revealed that 71% strongly agreed the layout was well- organized, 67% appreciated the smooth functionality, and 97% expressed increased interest and confidence in exploring or purchasing batik products after engaging with the site. Open- ended comments praised the website's aesthetic appeal and cultural richness, while also

suggesting enhancements such as mobile responsiveness and additional interactive features. These insights informed the final iteration of the website, ensuring it remained user-centered and purpose-driven. As supported by Rubin & Chisnell (2008), collecting direct user feedback is essential in usability testing to create digital platforms that truly meet user expectations and foster meaningful engagement.

4.0 CONCLUSION

In conclusion, the development of the Imarazak website has proven to be an effective digital platform for promoting traditional batik culture and enhancing brand visibility. Through a user- centered design approach, the website successfully improved user experience, increased public awareness, and supported online engagement with The Batik House by Imarazak. The positive feedback from users affirms the importance of combining cultural identity with modern digital strategies to sustain heritage-based businesses in the digital age.

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Video Dokumentari Eksplorasi Biodiversiti Dan Pemuliharaan Di Taman Negara Tanjung Piai, Pontian, Johor

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ABSTRAK

Ekopelancongan adalah lawatan yang menjurus kepada pemuliharaan alam sekitar serta memberikan manfaat kepada komuniti tempatan melalui penglibatan mereka. Setiap kawasan ekopelancongan mempunyai impak pembangunan yang tersendiri. Kajian ini dijalankan di Taman Negara Tanjung Piai, Pontian, Johor, yang terkenal sebagai titik paling selatan di benua Asia dan merupakan kawasan hutan paya bakau yang kaya dengan biodiversiti. Dokumentari ini terbahagi kepada empat siri pendek yang memfokuskan kepada latar belakang taman negara, spesies pokok bakau, kepelbagaian hidupan liar, serta usaha pemuliharaan alam sekitar. Objektif utama projek ini adalah untuk mendokumentasikan dan menyebarkan maklumat berkaitan nilai ekologi Taman Negara Tanjung Piai serta meningkatkan kesedaran awam terhadap kepentingan pemeliharaan alam sekitar. Kaedah pengumpulan data melibatkan kajian lapangan, rakaman video, sesi temu bual bersama pegawai taman serta pemerhatian langsung terhadap flora dan fauna. Penemuan daripada projek ini menunjukkan bahawa Taman Negara Tanjung Piai merupakan habitat penting bagi pelbagai spesies bakau seperti Rhizophora apiculata dan Avicennia alba, serta hidupan liar seperti ketam bakau, burung bangau, lotong kelabu dan pelbagai spesies burung migrasi. Selain itu, pihak taman juga giat menjalankan program konservasi dan pendidikan alam sekitar untuk pelawat dan komuniti setempat. Kajian ini diharapkan dapat memperkenalkan keunikan Taman Negara Tanjung Piai kepada khalayak, malah turut menekankan pentingnya pemuliharaan alam semula jadi demi kelestarian generasi akan datang.

Kata kunci: biodiversiti, ekosistem, hutan bakau, pemuliharaan, taman negara tanjung piai

1.0 PENDAHULUAN

Tujuan projek ini adalah untuk menghasilkan sebuah video dokumentari yang mempromosikan Taman Negara Tanjung Piai sebagai destinasi ekopelancongan yang unik di Malaysia. Terletak di Johor, kawasan ini terkenal dengan kedudukan geografinya sebagai titik paling selatan benua Asia serta kekayaan ekosistem hutan bakau yang menjadi habitat kepada pelbagai flora dan fauna. Dokumentari ini bertujuan menonjolkan keindahan alam semula jadi, kepelbagaian biodiversiti, serta usaha pemuliharaan yang dijalankan di kawasan tersebut melalui pendekatan visual yang menarik. Usaha ini juga bertindak sebagai alternatif kepada kaedah promosi sedia ada yang kurang berkesan dan tidak banyak menggunakan media visual. Oleh itu, video dokumentari ini diharap dapat meningkatkan kesedaran masyarakat, menarik minat pelancong, serta menggalakkan pemeliharaan Tanjung Piai sebagai warisan alam sekitar negara.

1.1 LATAR BELAKANG KAJIAN

Penghasilan video dokumentari tentang Taman Negara Tanjung Piai ini bertujuan untuk mendokumentasikan keunikan ekosistem bakau serta mengetengahkan kepelbagaian flora dan fauna yang terdapat di kawasan tersebut. Dokumentari ini juga berfungsi sebagai bahan visual informatif yang boleh digunakan oleh pelbagai pihak seperti agensi kerajaan, institusi pendidikan dan pelancong bagi memahami kepentingan menjaga warisan alam ini. Melalui penceritaan visual, elemen sinematografi dan penjelasan saintifik secara ringkas, dokumentari ini diharap dapat menyampaikan mesej pemuliharaan dengan lebih berkesan berbanding kaedah konvensional. Ia juga dapat mengangkat nilai estetika dan kepentingan sains alam sekitar dalam satu bentuk yang mudah difahami dan menarik minat

khalayak. Namun begitu, kesedaran masyarakat terhadap kepentingan ekosistem bakau masih kurang. Oleh itu, pendekatan kreatif seperti penghasilan video dokumentari alam sekitar boleh dijadikan sebagai medium pendidikan dan kesedaran yang berkesan kepada masyarakat umum, terutamanya generasi muda.

Malaysia merupakan sebuah negara yang kaya dengan khazanah alam semula jadi termasuk kawasan hutan bakau yang memainkan peranan penting dalam keseimbangan ekosistem pesisir. Salah satu kawasan yang menjadi tumpuan dalam pemeliharaan habitat ini ialah Taman Negara Tanjung Piai, yang terletak di hujung selatan benua Asia, dalam daerah Pontian, Johor. Kawasan ini bukan sahaja dikenali sebagai titik paling selatan di benua Asia, malah diiktiraf sebagai kawasan tanah lembap berkepentingan antarabangsa di bawah Konvensyen Ramsar. Taman Negara Tanjung Piai mempunyai ekosistem bakau yang unik dan kaya dengan pelbagai spesies flora dan fauna. Tumbuhan bakau seperti Rhizophora apiculata dan Avicennia alba menjadi benteng semula jadi yang melindungi pantai daripada hakisan, manakala pelbagai spesies haiwan seperti ketam bakau, burung bangau, monyet, dan ikan belacak menjadikan kawasan ini sebagai habitat semula jadi mereka. Keseimbangan antara flora dan fauna dalam ekosistem bakau ini bukan sahaja menyumbang kepada biodiversiti negara tetapi juga kepada kestabilan iklim dan ekonomi komuniti setempat yang bergantung kepada ekopelancongan.

1.2 PERNYATAAN MASALAH

Malaysia mempunyai ekosistem hutan bakau yang amat penting kepada kelestarian alam sekitar, khususnya di kawasan pesisir pantai. Taman Negara Tanjung Piai, Johor, merupakan salah satu kawasan tanah lembap yang diiktiraf di bawah Konvensyen Ramsar kerana nilai ekologi dan biodiversitinya yang tinggi (Department of Irrigation and Drainage Malaysia, 2021). Kawasan ini menjadi habitat kepada pelbagai spesies flora seperti Rhizophora apiculata dan Avicennia alba, serta fauna seperti ikan belacak, ketam bakau, dan pelbagai spesies burung.

Namun begitu, kesedaran masyarakat terhadap kepentingan ekosistem bakau di Malaysia masih berada pada tahap yang membimbangkan (WWF-Malaysia, 2020). Ramai tidak menyedari bahawa hutan bakau bukan sahaja penting sebagai habitat semula jadi tetapi juga sebagai pelindung pantai, penstabil karbon, dan penyokong biodiversiti marin. Tambahan pula, ancaman seperti pencemaran, pembangunan tidak lestari, dan perubahan iklim telah menyebabkan kemerosotan kawasan bakau, termasuk di Johor (Samsudin et al., 2018).

1.3 OBJEKTIF KAJIAN

Menilai keberkesanan video dokumentari sebagai kaedah komunikasi alam sekitar dalam menyampaikan mesej pemuliharaan dan meningkatkan kefahaman khalayak terhadap isu alam sekitar secara visual.

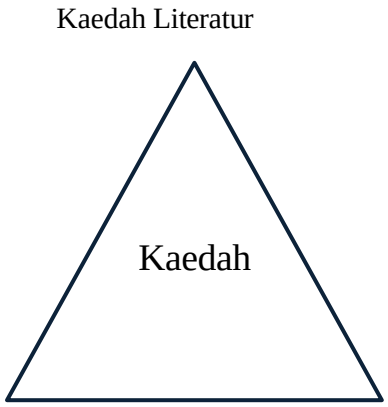
1.4 SOALAN KAJIAN

Apakah kaedah yang paling mudah dan efektif untuk menarik perhatian pengunjung melalui media visual?

1.5 SKOP KAJIAN

Skop kajian ini memfokuskan kepada penghasilan dan analisis video dokumentari mengenai ekosistem bakau serta kepelbagaian flora dan fauna di Taman Negara Tanjung Piai, Johor. Kajian dijalankan sepenuhnya di kawasan taman negara tersebut, khususnya di zon hutan bakau dan kawasan konservasi. Dokumentari ini menampilkan visual spesies tumbuhan seperti Rhizophora apiculata dan Avicennia alba, serta fauna seperti ikan belacak, ketam bakau dan burung air. Kandungan turut merangkumi elemen pemuliharaan dan nilai pendidikan alam sekitar. Skop turut merangkumi keseluruhan proses pembikinan dokumentari dari praproduksi, produksi hingga pascaproduksi. Sasaran utama dokumentari ini ialah pelajar, pendidik, pelancong dan pihak berkepentingan dalam pemeliharaan alam sekitar. Tempoh kajian dijalankan dalam masa satu semester yang meliputi fasa penyelidikan, penggambaran, penyuntingan dan penilaian kandungan.

2.0 METODOLOGI KAJIAN



Rajah 2.0: Triangulasi

Projek ini menggunakan pendekatan kaedah campuran yang melibatkan kedua-dua kualitatif dan kuantitatif. Kajian literatur dijalankan untuk mengenal pasti teori dan dapatan terdahulu berkaitan literasi awal untuk mencipta video dokumentari tentang ekosistem bakau flora dan fauna semasa kaedah pemerhatian dan temubual yang dijalankan. Data dikumpul melalui temubual dan pemerhatian untuk menilai pemahaman tentang ekologi bakau, dan nilai pendidikan. Cerapan kualitatif tambahan telah dikumpulkan melalui temu bual separa berstruktur dengan kakitangan taman dan pendidik, membantu triangulasi penemuan dan memastikan pemahaman yang menyeluruh tentang keberkesanan video dokumentari. Data pemerhatian mengenai corak interaksi pengguna dan maklum balas telah digunakan untuk memperhalusi produk akhir dan mengesahkan kesan pendidikannya.

3.0 PERBINCANGAN

Video dokumentari ini merupakan satu pendekatan kreatif dalam mengetengahkan isu pemuliharaan alam sekitar dengan memberi tumpuan kepada ekosistem bakau serta kepelbagaian flora dan fauna di Taman Negara Tanjung Piai. Dokumentari ini melalui proses seperti perancangan, penyelidikan kandungan, penggambaran di lokasi, dan penyuntingan. Lokasi ini dipilih kerana statusnya sebagai tanah lembab bertaraf antarabangsa dan kekayaan biodiversitinya. Walaupun berdepan cabaran seperti cuaca tidak menentu dan kekangan logistik, hasil akhir dokumentari berjaya disiapkan dengan pendekatan visual yang menarik dan informatif.

Dokumentari ini bukan sahaja menjadi bahan tontonan, malah berfungsi sebagai alat promosi dan pendidikan yang mampu meningkatkan kesedaran masyarakat tentang pentingnya pemeliharaan ekosistem bakau. Ia juga memperkenalkan keunikan khazanah semula jadi negara, sekaligus menyemai rasa tanggungjawab terhadap alam sekitar melalui medium komunikasi visual yang berkesan.

3.1 PRA PRODUKSI

Pembangunan video dokumentari untuk Taman Negara Tanjung Piai Pontian Johor ini melibatkan perancangan awal termasuk penetapan objektif dokumentari, penyelidikan kandungan, pembangunan skrip dan storyboard, serta penyusunan jadual penggambaran. Penyelidikan dilakukan melalui kajian literatur, temu bual dengan pihak pengurusan Taman Negara, dan lawatan tapak. Maklumat yang diperoleh digunakan untuk membentuk naratif yang relevan dan autentik. Pemilihan lokasi penggambaran, senarai soalan untuk naratif suara latar, serta senarai peralatan teknikal juga dirancang dalam fasa ini.

3.2 PRODUKSI

Penghasilan video dokumentari Taman Negara Tanjung Piai Pontian Johor dilaksanakan melalui proses produksi yang rapi, di mana setiap elemen visual seperti persekitaran, dan peralatan direka berasaskan rujukan yang bersesuaian. Pasukan produksi memanfaatkan pelbagai perisian seperti Adobe Animate, Adobe After Effects dan Adobe Premiere Pro untuk memastikan keselarasan antara visual, narasi dan elemen bunyi, seterusnya menghasilkan pengalaman tontonan yang harmoni.

3.3 PASCA PRODUKSI

Tujuan ini melibatkan proses penggambaran di lokasi sebenar, iaitu di Taman Negara Tanjung Piai. Berbagai teknik pengambilan gambar telah digunakan seperti rakaman sudut luas, close- up, serta rakaman dari udara menggunakan dron bagi merakam keunikan dan kepelbagaian flora dan fauna yang terdapat di kawasan tersebut. Proses penggambaran dijalankan mengikut jadual yang telah dirancang dengan mengambil kira faktor seperti keadaan cuaca dan aspek keselamatan. Sepanjang penggambaran, pasukan produksi juga memastikan pematuhan terhadap garis panduan yang ditetapkan oleh pihak taman demi menjaga kelestarian ekosistem semula jadi.

4.0 KESIMPULAN

Secara keseluruhannya, pembikinan video dokumentari mengenai ekosistem bakau, flora dan fauna di Taman Negara Tanjung Piai telah berjaya mencapai objektif utamanya dalam mengetengahkan keunikan dan kepentingan kawasan ini sebagai salah satu khazanah alam semula jadi negara. Melalui pendekatan visual yang kreatif, dokumentari ini bukan sahaja memperlihatkan kepelbagaian biodiversiti dan keindahan alam sekitar, malah turut menyampaikan mesej pemuliharaan dengan cara yang lebih mudah difahami dan menarik perhatian penonton.

Walaupun berdepan dengan pelbagai cabaran teknikal dan logistik semasa penggambaran, hasil dokumentari ini membuktikan bahawa media visual mampu menjadi medium komunikasi berkesan dalam mendidik dan meningkatkan kesedaran masyarakat terhadap isu-isu alam sekitar. Penghasilan dokumentari ini juga diharap dapat menyumbang kepada usaha promosi strategik Taman Negara Tanjung Piai sebagai destinasi ekopelancongan, pendidikan dan penyelidikan yang bernilai tinggi. Dengan adanya bahan visual ini, pelbagai pihak dapat melihat sendiri pentingnya memelihara dan menghargai ekosistem bakau sebagai aset semula jadi negara yang tidak ternilai.

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Video Infographic of JBEES's Promotion Strategy

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ABSTRACT

This study focuses on developing a dynamic infographic or video to effectively present JBEES's promotional plan and enhance its overall marketing strategy. Recognizing the critical role of visually motivated content in today's digital environment, this research aims to optimize brand visibility and customer interaction for JBEES. The objective is to create an engaging visual tool that precisely describes JBEES's approach to promotion within the contemporary honey market, while also expanding its reach and fostering stronger engagement with a diverse audience. The project employs a qualitative methodology, comprising a comprehensive review of current literature on honey marketing and the potent use of infographics and videos in communication. This includes a thorough evaluation of existing honey marketing channels to identify best practices, coupled with an exploration of the potential of graphics to serve as a dynamic and persuasive promotional medium. The aim is to create a well-designed and efficient visual depiction that effectively communicates JBEES's mission and values, specifically for the honey market. The anticipated outcome of this endeavour is the development of a practical and highly accessible infographic or video. This visual tool is designed to empower JBEES to connect with new audiences, effectively promote sustainable kelulut farming practices, and ultimately broaden awareness of the organization's contributions to the local agricultural landscape. The expected result is an interesting infographic or video ready for JBEES to use in growing its audience and enhancing its promotional impact, thereby offering useful information on the strategic use of visual media for supporting agricultural products.

Keywords: JBEES, promotion strategy, stingless beekeeping, sustainable kelulut farming, video infographic

1.0 INTRODUCTION

In an era where digital communication dominates, effectively engaging audiences requires more than traditional outreach methods especially for organizations like Persatuan Usahawan Lebah Kelulut Johor (JBEES), which aims to promote sustainable stingless bee farming. This study focuses on the development of a video infographic as a strategic tool to introduce JBEES to new farmers and higher education institutions, convey its mission, and highlight the benefits of kelulut honey production. Guided by three core objectives identifying the best visual strategies, producing an engaging and accurate video, and evaluating its impact this project adopts a qualitative approach through interviews and observations to ensure the final product is both informative and compelling. By combining storytelling with visual design, the video infographic is intended to raise awareness, build trust, and spark greater interest in sustainable agriculture, positioning JBEES as a key player in Malaysia's eco-entrepreneurial landscape.

1.2 Background Research

In today's rapidly evolving digital landscape, organizations are increasingly challenged to adopt modern and engaging communication strategies to effectively disseminate information and foster public awareness (*Digital Marketing Strategies in Increasing the Competitiveness of Agricultural Products in the Digital Economy Era*, 2024). Traditional methods of outreach

often fall short in capturing the attention of a digitally-savvy audience, leading to limited understanding and engagement, particularly for specialized fields. This project addresses the pressing issue of low public awareness surrounding JBEES's crucial role in promoting sustainable *kelulut* farming and the benefits of stingless beekeeping (Stingless bees farming in Malaysia: a policy analysis matrix (PAM), n.d.). Recognizing that conventional approaches are insufficient to attract new farmers, engage Higher Education Providers (HEP), or draw interest from the community and investors (*Agricultural marketing strategies in the digital era: improving the competitiveness of local products*, 2024), this research proposes the development of a video infographic. This modern digital tool is designed to provide an interactive and visually compelling means of introducing JBEES, clarifying its mission, and effectively conveying the significant impact of its operations on agriculture, economy, and environment, thereby overcoming the limitations of static information dissemination and fostering greater understanding and participation (Zhang et al., 2023).

1.3 Persatuan Usahawan Lebah Kelulut Johor (JBEES)

Persatuan Usahawan Lebah Kelulut Johor (JBEES) is a pivotal non-governmental organization (NGO) based in Johor, Malaysia, dedicated to advancing the region's stingless bee farming industry. JBEES's core mission revolves around establishing Johor as a prominent producer of high-quality *kelulut* honey in Southern Malaysia and Southeast Asia by fostering sustainable practices and empowering local farmers. The organization actively addresses significant industry challenges such as low public awareness, a lack of youth engagement in entrepreneurial opportunities, and the erosion of consumer trust due to fraudulent practices. To overcome these hurdles, JBEES strategically employs various promotional approaches, including the development of engaging digital tools like video infographics, to effectively communicate its mission, showcase authentic honey production, and highlight the economic and ecological benefits of stingless beekeeping, ultimately aiming to increase participation and investment in the sector (Pachpute & Pardeshi, 2025).

1.4 Problem Statement

Persatuan Usahawan Lebah Kelulut Johor (JBEES) plays a vital role in fostering the growth of Johor's stingless bee honey industry; however, the organization faces several interconnected challenges that impede the sector's full development and limit its potential contributions to the regional and national economy. A primary concern is the limited awareness among the younger generation regarding the viable entrepreneurial opportunities presented by stingless bee farming.

This disconnect creates a significant hurdle in attracting new entrants to the field, despite the increasing consumer demand for stingless bee honey and the perceived accessibility of the market through digital platforms. Simultaneously, consumer confidence has been compromised by the prevalence of fraudulent practices, including the sale of adulterated or misrepresented honey products. This issue erodes trust in the market and makes it difficult for consumers to verify the authenticity and quality of honey purchased, particularly through online channels, creating an environment where unscrupulous sellers can exploit the demand for genuine products. Furthermore, when considering the broader economic landscape, Johor's current contribution to Malaysia's overall stingless bee honey production remains relatively low, indicating that the sector is not yet operating at its optimal capacity and that targeted interventions are necessary to enhance productivity and market competitiveness.

1.5 Purpose of The Promotion Video

The primary purpose of this video infographic, referred to as a "promotion video" by the user, is to significantly enhance public awareness and understanding of JBEES (Persatuan Usahawan Lebah Kelulut Johor) and its vital role in promoting sustainable *kelulut* (stingless bee) farming. This involves effectively introducing the organization to new farmers, Higher Education Providers (HEP), and the general community, while also addressing existing awareness gaps regarding JBEES's mission and entrepreneurial opportunities within the stingless bee industry. Furthermore, the video aims to educate consumers about the characteristics of authentic *kelulut* honey, thereby rebuilding trust, and to inspire individuals to consider stingless beekeeping as a viable entrepreneurial venture and engage with JBEES's community and programs. Ultimately, it serves as a professional and engaging presentation tool to attract the interest of various stakeholders, including potential investors and collaborators, fostering a deeper understanding of JBEES's operations and objectives, all with the goal of empowering local farmers, safeguarding the environment through sustainable practices, and establishing Johor as a leading producer of high-quality *kelulut* honey.

1.6 Research Objective

The successful outreach and engagement of the JBEES organization with new and potential collaborators hinge on a clear and strategic approach to communication. Therefore, the first primary objective of this project is to investigate and identify the most effective communication methods for introducing the JBEES organization and its multifaceted initiatives to key new stakeholders. This includes, but is not limited to, prospective farmers who could benefit from JBEES's programs and relevant Higher Education Providers (HEPs) who may serve as crucial partners in research, development, or educational dissemination. Understanding the preferred communication channels and messaging styles of these distinct groups is paramount to establishing initial contact, fostering interest, and building a foundation for fruitful partnerships.

Building upon the insights gained from the initial objective, the second core aim is to design and produce a compelling video infographic that clearly and effectively introduces the JBEES organization, its core activities, and its value proposition to the identified stakeholders. In an era of digital information consumption, a well-crafted video infographic offers a dynamic and accessible medium to convey complex information concisely. This visual tool will be developed to encapsulate the essence of JBEES, highlighting its mission, key projects, benefits for stakeholders, and overall impact, thereby serving as a primary resource for initial engagement and information dissemination.

2.0 METHODOLOGY

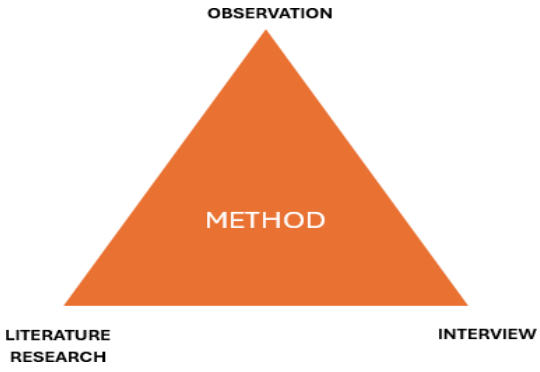

Figure 1: Method

To fulfill the objective of identifying the target audience, key message, and preferred animation style, this project employed a combination of interviews, direct observation, and literature review. Interviews with JBEES members and stakeholders provided in-depth insights into the organization's goals, values, and communication challenges. These conversations helped define the core message that the video infographic needed to convey and clarified who the intended viewers were, particularly young aspiring farmers and educational institutions. Direct observations conducted at JBEES farms allowed the team to better understand daily operations, capture real-life visual elements, and determine an animation style that would authentically reflect the work and environment of JBEES. Complementing this, a literature review of relevant academic sources, visual communication studies, and promotional design case studies informed the visual and narrative structure of the infographic, ensuring that the final output aligned with proven strategies for viewer engagement and message retention.

To address the development of a consistent multi-channel campaign, the insights gathered from these methods were used to design cohesive visual branding and messaging that could be applied across various platforms. The consistent use of JBEES's color palette, typography, logo placement, and tone of voice was informed by both observational findings and industry best practices identified in the literature. Interviews further revealed which digital platforms were most relevant to JBEES's target audience, allowing the campaign to be optimized for social media channels, websites, and educational settings. This strategic combination of methods ensured the infographic was not only visually effective but also adaptable across multiple platforms, supporting JBEES's broader outreach and promotional goals.

3.0 RESULTS AND DISCUSSION

3.1 Video Infographic

Figure 2: Thumbnail

The development of the "Video Infographic of JBEES's Promotion Strategy" is a structured process encompassing pre-production, production, and post-production phases, designed to effectively introduce JBEES and promote sustainable *kelulut* farming. The pre-production phase involves foundational research, including qualitative data collection from JBEES members and literature reviews, to inform the project's direction and propose the video infographic as a solution to address challenges like low public awareness. This groundwork

leads into the production phase, where the actual video is crafted through storyboard implementation, detailed background design with specific color palettes, the creation of engaging infographics, and the integration of voiceovers, all while adhering to a storyline structured into series like "Introduction to JBEES and Its Benefits." Finally, the post-production phase ensures the video's polish through rigorous editing and refinements, culminating in final rendering and preparation for presentation and publishing to the target audience.

3.1 Pre-Production Phase

The development of the video infographic for JBEES was deeply informed by the insights gained from various study materials and direct interviews, shaping its conceptualization and overall execution. This digital presentation was meticulously designed to articulate JBEES's core mission, highlight its operational aspects, and provide a clear visual narrative of its contribution to sustainable *kelulut* farming. Every sequence and transition within the video infographic was carefully planned and organized through a rigorous storyboarding process. A key finding from the SWOT analysis revealed that the project's primary strength lay in its novel and genuine visual appeal, which was expected to draw significant viewership. Conversely, a recognized limitation was the inherent inability of the video infographic format to convey tactile sensations. Nevertheless, the integration of social media platforms presented a substantial opportunity for reaching a global audience, though this was tempered by the threat posed by the sheer volume of competing digital content, which could potentially dilute the impact of JBEES's message.

3.2 Production Phase

The crafting of the JBEES video infographic involved a meticulous production process, where visual elements like characters, backdrops, and props were conceived based on specific references pertinent to JBEES's mission and the unique aspects of the stingless bee industry. Utilizing a suite of software including Adobe Animate, Adobe After Effects, and Adobe Premiere Pro, the creative team diligently worked to ensure the visuals were perfectly synchronized with the narration and sound, creating a cohesive viewing experience. A core aim throughout this phase was to captivate the audience by seamlessly blending informative content with engaging and enjoyable elements, all while maintaining a strong connection to authentic, traditional practices relevant to JBEES's context.

3.3 Post-Production Phase

The final stage of refining the JBEES video infographic involved a meticulous post-production process. This critical phase encompassed precise video and audio editing, the seamless integration of all visual assets, and detailed color grading to achieve a consistent and impactful aesthetic. Additionally, careful sound mixing was performed to ensure optimal audio quality. Throughout these steps, paramount importance was placed on achieving impeccable synchronization between the visuals and the accompanying sound, alongside maintaining crystal-clear picture quality. Once all these enhancements were complete, the perfected video infographic was readied for broad distribution across various digital channels.

3.4 Questionnaire Findings

Based on the provided Google Form response data, a total of 67 respondents participated in the survey regarding the JBEES's Promotion Strategy video infographic. The majority of respondents were male (approximately 82%) and fell within the 19-25 age group (approximately 70%). Malay individuals constituted the largest racial group (approximately 88%), and students were the predominant occupation (approximately 91%). Regarding prior

awareness, about 53.7% of respondents indicated they did not know about JBEES before watching the video infographic. The video infographic received generally positive feedback on its perceived quality, with an average rating of approximately 1.64 for "Video Quality," 2.18 for "Dynamic Elements," and 2.03 for "Text & Information Clarity" on a scale where 1 is excellent and 5 is poor.

The open-ended comments provided detailed feedback, with many respondents expressing overall satisfaction, using phrases like "I like everything" and "Very good". However, several suggestions for improvement were also noted. Key areas for enhancement included visual aspects such as changing background colors and general color usage, and developing more expressive or Johor-symbolic characters. Audio-related suggestions included adding sound effects and incorporating more engaging background music. Content and informational improvements were also suggested, such as adding more introductory information, enhancing information clarity, and expanding on specific objectives or topics. Other feedback pertained to pacing and timing of the video, audience targeting, and a general desire for "more infographic and animation".

The survey on the JBEES Promotion Strategy video infographic, involving 67 respondents primarily characterized as young adult (19-25) Malay male students, revealed its significant impact as an initial awareness tool, with over half (53.7%) previously uninformed about JBEES. The video received generally positive feedback on its technical and informational quality, with average ratings approaching "excellent" for video quality (1.64), dynamic elements (2.18), and text/information clarity (2.03), corroborated by appreciative open-ended comments such as "Very good." However, detailed qualitative feedback also provided a clear trajectory for enhancement, highlighting opportunities to refine visual aspects (e.g., color schemes, character design with Johor symbolism), improve audio engagement (e.g., sound effects, background music), deepen informational content (e.g., more introductory details, expansion on objectives), and further increase the dynamism through more extensive use of infographics and animation, thereby suggesting a strong foundation with clear paths for future optimization.

4.0 CONCLUSION

The goal of the project was to create an engaging and informative video infographic to introduce JBEES and its mission to a wider audience, particularly targeting youth, aspiring farmers, and academic institutions. The video aimed to present JBEES not just as an organization, but as a movement promoting sustainable stingless bee (kelulut) farming and local entrepreneurship. Through a blend of visual storytelling, informative narration, and purposeful animation, the infographic effectively conveyed the value of kelulut honey production while highlighting the ecological and economic contributions of JBEES. Many viewers who had little or no prior knowledge of the subject found the video insightful and well-crafted, with a clear structure and appealing design that made the content easy to understand and remember.

The project successfully achieved its core objectives: defining the target audience and message, developing a consistent visual and narrative style, and evaluating its impact through real-world feedback. Audience responses indicated strong approval of the infographic’s visual quality, clarity of information, and overall engagement. At the same time, the findings revealed meaningful opportunities for improvement. Suggestions included incorporating stronger elements of Johor's local identity, enhancing the emotional tone of the background music, and enriching the content with more specific details about JBEES's programs and achievements.

These reflections emphasized the importance of cultural relevance and personalized storytelling, reinforcing that effective communication in digital media must go beyond aesthetics to build a genuine connection with viewers.

Looking ahead, this project highlights several directions for future research and development. One limitation was the relatively narrow demographic sample, primarily consisting of students in a specific age range. Expanding the reach of future testing to include working adults, investors, educators, and community leaders could yield a more diverse perspective and broaden the infographic's appeal. In addition, exploring the use of interactive media, such as clickable video elements or platform-specific adaptations, could enhance audience engagement and shareability. By continuing to refine both content and delivery methods, JBEES and similar organizations can leverage visual media not only to promote their missions but also to foster deeper public understanding and participation in sustainable local industries.

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Visualizing Sustainable Craftmanship: The Use of 2D Animation and Live Action in Promoting Pineapple Fiber Yarn

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ABSTRACT

The research discusses is to make an educational video for young adult and tourists. The main reason for writing this is to make the yarn making process from pineapple leaves entertaining and clear to tourists to follow. Since these learners have plenty of curiosity and energy, the project offers traditional knowledge in a way that is interesting, easy to follow and encourages them to learn important things. The narration of the story is from both 2D animation and live-action. I created a character in the 2D part that looked just like a real artisan from Pontian, Johor. The character guides the readers with a detailed description of how to make pineapple yarn. Having everything move in animation brings excitement and fun to the process. In addition, live-action clips reveal the authentic process of making eco-friendly yarn. The clips connect you to the world and show viewers the expertise needed for sustainable weaving. Both types of images and videos make learning enjoyable and simple for students. Animated videos boost the fun and make it simpler for children to learn about crafts they don't recognize from traditional media. Besides, the live-action part gives us a truthful and relatable glimpse of the tasks performed. Doing this helps keep viewers interested and also helps them relate to the craftspeople on an emotional level. The project benefits culture and the environment by sharing inventive uses of the things found locally. It explains that using traditional skills can matter today and that products made from pineapple leaves are helpful and eco-friendly. The video supports cultural identity by introducing viewers to the techniques and handcrafts used by Malaysians in Johor nowadays. On top of that, it supports the community by highlighting local skills in crafting and introducing pineapple fiber yarn as something special and worthwhile. In addition, it teaches others about sustainable crafting, helping to build local businesses in this area. This project works to link traditions from the past with new ideas for the future, helping youth better understand cultural customs and encouraging them to think about sustainability and creativity differently.

Keywords: 2d animation, cultural heritage, educational video, live action, pineapple fiber yarn

1.0 INTRODUCTION

This initiative aims to enhance knowledge about both culture and the environment by blending animations and live footage to explain pineapple fiber yarn. We use the power of 2D animation and live-action film to clearly present how artisans in Pontian, Johor use pineapple leaves to make yarn. The goal is to deliver a message to tourists and students between the ages of 12 and 17 that is easy to absorb and interesting to see. Thanks to this presentation, viewers gain access to information on an authentic Malaysian heritage craft in a style that is up to date, understandable and environmentally friendly. This project is designed to educate and inspire younger people about Malaysian traditional crafts, with a heavy focus on conserving the environment. The makers of the video simplify the process of making yarn using agricultural waste by blending two creative approaches to storytelling. Instead of just showing the process, it ensures it is fun and understandable for those who watch visual media all the time. According to a study by Neta, Yulius and Nasrullah (2020), multimedia methods like animation and live-action raise learning results, motivation and recall when put against standard teaching instruments. That's why the project's main mission is to improve awareness, cultural

understanding and to encourage sustainability through creative learning materials.

On top of that, this initiative focuses on keeping local artisans active as rapid developments in technology and the internet attract more attention. I consider pineapple fiber yarn making to be a cultural tradition that should be recognized and handed down to the next generation. Mixing information with visuals, the project provides care for the artisans and the viewers, helping both groups form connections and respect eco-friendly creations. With an industry focused on quick fashion and industrial cloth production, this project persuades people to consider the sources and effects of what they wear and thus value sustainability as passed down from tradition.

1.1 Research Objective

To develop storytelling techniques in 2D animation + live action that enhance public engagement and awareness regarding sustainable textiles.

The aim of this objective it to come up with creative storytelling strategies blending 2D animation and live video to inform people and involve the community regarding pineapple fiber yarn. The objective is to make a story that mixes actual footage of weaving yarn with a colorful animated host character. The aim is to provide an informative and touching moment for viewers which lets them see the technical parts as well as learn about the significance and importance of the process to local culture and environment. By concentrating on reaching everyone, finding a familiar tone and being direct, the storytelling highlights how the topic of sustainability and craftsmanship can be accepted and understood by all. It also ensures the narrative moves smoothly, the visuals are pleasing and different sounds help bring attention to actors and the scenes. The 2D animation character inspired by Puan Muna communicates the traditions linked to the craft, allowing the spectators to recognize its culture and history. The creative approach which brings together document-like visuals with animation, demonstrates the benefits of combining styles to explain, protect traditions and catch the interest of young audiences who quickly learn from any dynamic project.

2.0 METHODOLOGY

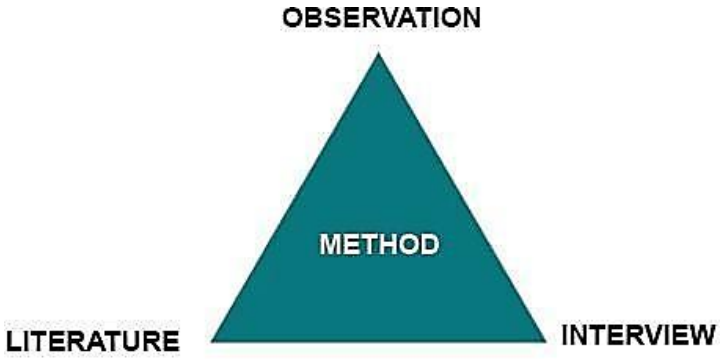

Figure 1: Method

Based on figure 1, In this research, three approaches are used to collect data: observing, studying materials in the form of literature and conducting interviews. The approach is taken to make sure students learn about the subject from academic, practical and cultural standpoints. These different processes together support the making of an animation that explains how pineapple fiber yarn is produced using live-action scenes. In the beginning, the researcher

visited the factory, Perniagaan Benang Serat Nanas M&Z in Pontian, Johor and observed the steps taken by the artisans to produce handmade pineapple fibers. From personal experience, I could see more clearly how everything related to the craft functions. They helped the team prepare visual plans and provided accurate details for the film's story through their honest records of the work taking place. To make sure the animation was true to life and aware of cultural traditions, field notes and video recordings were kept as references.

In addition, by studying prior work, the theory used in the study was established. Scholarly pieces on multimedia education, animation used to save cultural heritage and sustainable marketing of textiles were part of this process. Animation and live-action were proven to improve awareness and aid in remembering what you learn, mainly among the younger generation. It also showed how other studies used multimedia to improve understanding of cultural issues and encourage environmentally friendly actions. Following the guidelines in the approved literature, the project followed the best procedures for communication, design and schools outreach. In the end, key individuals such as artisans, business owners and members of the local community were interviewed using semi structured interviews. The information from these interviews helped us see the importance of pineapple fiber yarn in people's lives and evaluate how well current advertising was reaching consumers. Stories told during interviews helped us determine how we would voice the animation, how the story should be created and how to appeal to the audience emotionally. Using all three methods helped ensure that the project looked good and was also supported.

3.0 RESULTS AND DISCUSSION

3.1 Video Development

Figure 2: Thumbnail

The making of the video was essential to this project and it was the main approach used to share information with the audience in an attractive manner. This video, entitled "Making Pineapple Fiber Yarn at M&Z" was designed to use both 2D animation and real-life sequences to describe how pineapple fiber yarn is created. The narrative was created with a young audience and tourists in mind by using both visuals and words that kept their attention and informed them. In the video, the main focus is on Puan Muna, a fictional guide who is like a real artisan from Pontian, Johor. She played a key part in explaining cooking techniques that seemed complicated by making them simple with effective illustrations. She showed viewers

each part of yarn production, starting with gathering it from pineapples and ending with the final spinning and weaving. Due to her cheerful attitude and colorful look, many people enjoyed watching her. The real artisans in their workshops demonstrated the genuine and significant traditions of the practice.

The real footage helped to back up the animation by highlighting that the techniques are done by skilled people in real life. Mixing animated scenes with real ones enabled the movie to bring out both the audience's creativity and their understanding. Developers paid a lot of attention to how the game looks and plays. The show's changes were well handled, pacing was slow enough and the narrators' words and the background soundtracks were paired to improve the experience. Using pictures, illustrations and a compelling story, the video made a traditional subject more interesting for viewers and helped them learn at the same time.

3.2 Questionnaire Findings

Table 1: Analysis of Demographic

Demographic Variable	Response Category	Number of Respondents	Percentage (%)
Ages	11-12 y/o	48	78.7
	13-15 y/o	10	16.4
	16/18 y/o	3	4.9
Gender	Male	31	50.8
	Female	30	49.2
Have you heard of pineapple fiber yarn before watching this video?	Yes	42	68.9
	No	19	31.1
Do you enjoy learning new things through videos?	Yes	56	91.8
	No	5	8.2

According to table 1 in section A, according to the data, the educational video managed to reach and affect the youth, mainly early teenagers. Among the respondents, 78.7% were between 11 and 12 years old, while the number dropped to 16.4% for ages 13–15, illustrating that the main age group targeted was very pleased with the result. They usually react better to animations and videos, mainly when presented in a fun or playful manner. The fact that there were almost equal amounts of males and females showed that the content was popular with both groups. This balance proves that the video's ideas, pictures and way of presenting them were welcoming to all. Even though the majority of those attending had already heard of pineapple yarn, they weren't very familiar with its manufacturing process or its cultural role. It helped to fill the lack of information by providing useful details. Besides, almost all of the respondents (91.8%) mentioned that videos are their preferred way to learn which suggests that using animated and live-action videos is suitable for educating them. It confirms research which says young people have a greater reaction to material presented in multimedia lessons than in traditional ways. Some noted that watching the videos made it simpler to absorb and remember information. After viewing, more people showed a higher interest in traditional crafts and environmental preservation. Overall, this part of the case study proves the project targeted the right users who gained knowledge and awareness from it. These results confirm

that media outlets do reach young people well and present them with environmental and cultural information.

Table 2: Analysis of Usability

Response Category	Number of Respondents	Percentage (%)
Strongly Agree	27	44.3
Agree	21	34.4
Neutral	21	19.7
Disagree	1	1.6
Strongly Disagree	0	0
Total :		100

Table 2 shows that the items in Section B explored the viewers' relationships with the video such as how easy it was for them to use, the clarity of its aspects and how much they were engaged. Many participants pointed out that using 2D animation and live-action steps together was smooth, easy to watch and they enjoyed it. Such feedback means that the audience could easily follow the storytelling approach and the use of different media formats was not difficult for them. Instead of explaining things in a difficult way, the project arranged the changes from animation to live-action to happen in a smooth and logical way. As a result, the audience was able to follow how pineapple fiber yarn was produced, even if they did not have any prior knowledge. It was easy to navigate the video and the structure did not have any reported problems.

The participants appreciated how clear and informative they found the video, since it wasn't made to seem like a lesson. Various people pointed out that watching the animation and real-life images made unfamiliar sections in the process clearer. animation and real-life footage helped in highlighting the techniques the company used. In addition, those who watched the video pointed out that its length was suitable, the pace was alright and the structure kept their attention. Additionally, most people did not find it hard to understand the story or operate the video settings which points to an easy-to-use interface. The outcome of the usability tests proves that the online platform for the video was made with care, held students' attention and served well as an educational tool for young students interested in sustainability and crafts.

Table 3: Analysis of content and educational impact

Response Category	Number of Respondents	Percentage (%)
Strongly Agree	41	67.2
Agree	17	27.9
Neutral	3	4.9
Disagree	0	0
Strongly Disagree	0	0
Total:		100

This table shows section C in the questionnaire focused on how much educational information and clarity were given in the video. Majority of viewers said that the video informed them and left them inspired. To be more specific, 67.2% of the sample strongly believed the video explained the process of making pineapple fiber yarn and 27.9% responded that the video did a good job. Most of the viewers believed that the educational content successfully supplied them with new information. Cooking enthusiasts liked the video because it made a difficult traditional process clearer with the help of animations and a step-by-step explanation. Puan Muna spreading information in an animated way ensured that the video was simpler and more accessible to everyone who saw it. The respondents who are younger highlighted that the video was more engaging because of its main character. Along with teaching, the method addressed why using this fiber was helpful to nature, how it is made in a sustainable way and how it is appreciated by people in different cultures

As a result, the viewers could see the big picture regarding the topic. Moreover, people became more interested in other traditional crafts or eco-friendly methods after seeing the video. Therefore, this means that the project provided new information and also incited feelings and ideas in people. Students thought it was useful that the video put the process into perspective for talks about the environment nowadays, showing them how valuable traditional crafts are currently. Some also said that the way the subject was taught allowed them to remember the important points, pointing to a strong recall of the lessons. Simply put, the video's objectives were reached and probably even surpassed, due to its ability to catch learners' attention and emotions around sustainability, tradition and local culture.

Table 4: Analysis of engagement and visual design

Response Category	Number of Respondents	Percentage (%)
Strongly Agree	41	67.2
Agree	12	19.7
Neutral	8	13.1
Disagree	0	0
Strongly Disagree	0	0
Total:		100

Answers to the questionnaire D, table 4 showed that viewers enjoyed the combination of animation and live scenes, all confirming that the use of both was effective. Two-thirds (67.2%) of respondents said that animated sections, live-action shots, the style of characters and motion graphics made the video easy to recall and enjoyed by them. Taking part in the feedback, everyone who saw the video spoke positively of the colors, smooth animation and animations all the time, often describing the video as "entertaining to watch" and "pleasing to see." Puan Muna, the animated guide, had a strong effect on many people. Her enthusiastic way of moving, cheerful manner and colorful outfits made the content more meaningful and close to the viewers' hearts. The inclusion of Hayao Miyazaki with real artisans in the same world made it easier for users to relate to the animation. Compliments were given for the techniques used which made making yarn look easy but still eye-pleasing.

Enjoying the story, many respondents commented on how it noted the value of keeping tradition in work and nature. The way the film showed things visually allowed me to sympathize with the makers and comprehend the difficult tasks they face. Music, ambient effects and interesting colors were used in the video to highlight the key parts. The design was very important for creating the right learning environment, most valued by youngsters who depend on visual information. Many participants said that the video kept them interested and didn't seem lengthy to watch. To sum up, the viewer interaction and the visuals highlight the fact that the video encouraged an interest in traditional and eco-minded habits by planning attractive and impactful scenes.

In short, the results from the questionnaire indicate that using blended media with 2D animation and live-action video helps in both education and cultural storytelling. Young viewers and tourists have been especially impressed and enlightened by how its faculty uses new learning tools. The feedback collected demonstrates that people found the video effective and meaningful which indicates that the project reached its desired outcomes. From the questions posed in the questionnaire, I could see that participants got pleasure from watching the video and also remembered what it presented. A large number of viewers liked the mix of visuals, narration and animated characters because they found them interesting and easy to grasp. The interesting way the author wrote managed to bring the topic of pineapple fiber yarn which might have seemed old-fashioned, closer to curious contemporary readers. It was stated that Puan Muna was specifically admired for her straightforward style which helped all viewers to understand yarn-making rituals and feel a part of the culture.

In addition, the data found that the video captured more than interest, it actually inspired people to explore traditional skills and sustainable methods. Many people commented that they would like to know more about the country's past and sustainable filmmaking after finishing the video. This points out that using multimedia helps to attract the audience, guiding them to correct choices and encouraging them to explore certain details further. It is also important to notice how creativity and education can work together. If educational material appeals to viewers' eyes and feelings, it tends to stay with them and make a bigger difference. It demonstrates that using animation and real video can add importance to any learning experience.

To sum up, the confirmation from the questionnaire was that this approach did the trick: everyone was involved, well-informed and motivated. It gave many people a fun opportunity to admire how pineapple fiber yarn is made and possibly motivated them to focus more on traditional arts. It is obvious that using different media to tell a story educates and forms emotional and cultural bonds with the audience.

4.0 CONCLUSION

The goal of the project was to tell the story in a compelling way by mixing 2D animation and live-action clips to capture more people's interest and awareness on pineapple fiber yarn. I am glad to report that the target was surpassed and reached in full. The films united these two visual styles to inform viewers, mostly young people and tourists, in a way that was fun, significant and interesting. The use of storytelling linked the old techniques to new technology, so the video was able to share its message with its audience and educate them on sustainability. A major benefit of the final video was that Puan Muna was there to walk the viewers through the learning in a friendly manner. She guided us through the complicated phases of yarn

production in a fun, simple and imaginative fashion. The film showed real-life scenes of experts producing the material at Perniagaan Benang Serat Nanas M&Z in Pontian, Johor, making the cultural background of this craft much more real. With these aspects in place, the narrative about sustainable craftsmanship was smooth, memorable and enjoyable to experience.

The audience confirmed through their comments that the approach was successful. The video turned out to be easy to follow, enjoyable to watch and offered educational benefits to most of the participants. Viewing the content has made many interested in creating environment-friendly objects and adopting old skills. This shows that the video not only gave facts but also encouraged viewers to reflect, get curious and respect local artisans' importance for a sustainable life. Specifically, the project helped show that traditional wisdom can be saved and transferred through the help of current technologies. With most focus on industry, this project helps us notice that traditional crafts are important and can be appreciated by people living in today's fast world. Using a blend of animations and footage from the real world, the project proved that modern and traditional elements can be used together for successful education. Its wider effect comes from the chance for educators to use it to support upcoming projects focusing on heritage and nature.

It shows that with careful thought, digital storytelling can result in positive changes, including becoming more interested in sustainability, valuing different cultures or relating more to the heritage of the area. As there is a greater awareness among educators, creative groups and local leaders to find new ways to connect with students, this multimedia project acts as a good example. Altogether, the project was successful and went beyond what was planned. It introduced fresh methods for cultural stories, made traditional facts accessible to the general public and increased love for sustainability among people. This shows the power media has in shaping how we learn, feel and behave to save both our cultural and environmental heritage.

ACKNOWLEDGEMENT
Several initiatives will be set in place to raise the educational, technical and cultural strengths of this project later on. Use of both AR and VR allows users to experience the whole yarn-making process as if they were there. Users have the chance to try pulling, drying and twisting fibers, making them better understand how the process works. Secondly, interactive quizzes, award points and achievement badges will be included in the project. Thanks to these features, younger audiences can be drawn in, remember the content better and enjoy learning at the same time. Adding various languages and having subtitles will make sure that the video appeals to viewers from different backgrounds in Malaysia and abroad. So, it will open up the message of sustainable tourism and caring for culture to tourists and students worldwide.

The fourth way is to place QR codes at special spots like museums, craft centers and community halls. After clicking these codes with their phones, users are directed to the educational content which helps them learn about culture wherever they go. Next, the project plans to try including Malaysian traditional crafts and eco-friendly materials, growing the multimedia series to spotlight several artisans and sustainable activities in the country. This method will encourage us to value different cultures and care for the environment.

In the end, agreements with schools will be set up so that the video is used in their curriculum. Enhancements such as downloadable worksheets and teacher guides, will be available to help

teachers in the classroom. With this long-term plan, the project will improve and support teaching about heritage and sustainability for people in the future.

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7 TEKNOLOGI KEJURUTERAAN PEMBUATAN (REKA BENTUK AUTOMOTIF)

Checking Fixtures for Reducing Defects: A Study on Minimizing Painting Defects (Orange Peel and Sagging) Caused by Unstable Painting Fixtures.

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ABSTRACT

Paint imperfections such as sagging and orange peel are common challenges in automotive production, often caused by unstable fixtures during the painting process. This study explores how instability affects surface quality and introduces a newly developed fixture designed to enhance stability and minimize these flaws. The research began by observing production issues directly and identifying core factors contributing to defects, such as misalignment and vibration. A new fixture concept was then designed, compared against alternative options based on key performance factors, and built using strong, reliable materials to endure operational conditions. After implementation, a substantial drop in defect rates was recorded with sagging reduced by nearly 39% and overall defects decreasing from 20,100 to 12,276. These findings confirm that improving fixture stability is a practical and economical way to increase paint quality and consistency in vehicle manufacturing.

Keywords: fixture stability, paint defects, automotive manufacturing, surface quality, process improvement.

1.0 INTRODUCTION

In manufacturing, checking fixtures are essential tools for ensuring the accuracy, stability, and alignment of components throughout production, playing a critical role in maintaining dimensional precision and consistent quality. Industries such as automotive, aerospace, and electronics rely on these fixtures to detect misalignments and deformations early, minimizing defects and reducing costly rework. Mamidwar et al. (2024) highlight that using advanced measurement tools and CAD technology in the design of checking fixtures greatly improves their effectiveness in identifying panel misalignments during assembly, which leads to better dimensional precision and higher product quality in automotive production (Mamidwar et al., 2024).

In recent years, ensuring the stability and precision of painting fixtures in automotive manufacturing has become increasingly crucial for achieving high-quality surface finishes and minimizing production defects. Instabilities such as wobbling and misalignment during the painting process can result in surface issues like sagging and orange peel, which compromise both the aesthetic and functional quality. Previous studies have investigated various approaches to tackle these challenges. Thomas et al. (2021) proposed a motor-driven system that integrates rotational and spray synchronization, showing improved surface finish and reduced processing time through enhanced fixture stability (Thomas et al., 2021) .In the field of quality monitoring, Xu et al. (2021) applied deep learning techniques to detect paint film defects, offering a reliable method for identifying surface imperfections caused by fixture misalignment or vibrations (Xu et al., 2021).These studies highlight the vital importance of fixture stability and automated

quality control in improving painting precision and minimizing rework in automotive production lines.

1.1 Problem Statement

In the automotive manufacturing industry, maintaining high-quality paint finishes is critical for both aesthetic appeal and customer satisfaction. Despite efforts to control painting parameters, paint defects such as sagging, orange peel, and uneven coating still occur, often as a result of inadequate or poorly maintained checking fixtures used during component inspection and positioning. These suboptimal fixtures can lead to misalignment or improper fitment, contributing to inconsistent paint quality and increased rework rates. Therefore, it is essential to investigate and optimize the use of checking fixtures to ensure accurate component placement and reduce the occurrence of paint defects in the production process.

Figure 1: Functional of the painting fixtures.

1.2 Objective

- To reduce rate of painting defects through the effective use of checking fixtures.

1.3 Research Scope

- Design and optimization of checking fixtures to enhance positioning accuracy and stability during the painting process.
- Evaluation of the impact of checking fixtures on reducing common painting defects such as orange peel and sagging.

2.0 LITERATURE REVIEW

2.1 Defect Control

The study by (Olalere & Ramdass, 2024) evaluates how quality improvement initiatives in the paint-shop section impact the reduction of production defects. Their findings emphasize the importance of maintaining part stability and precise positioning during manufacturing to reduce defect rates. This supports the premise that optimizing checking fixtures, by ensuring parts are securely held and consistently positioned, can significantly enhance inspection accuracy and minimize painting defects such as orange peel and sagging. The integration of stable fixtures

in the inspection process promotes proactive defect prevention rather than reliance on post-process corrections.

2.2 Checking Fixtures

In the research conducted by (Akhtar et al., 2019) the focus was on designing an optimized fixture for leakage testing machines to improve component handling and reduce inconsistencies in test results. The study highlights that poorly designed fixtures can lead to higher defect rates due to unstable positioning. This finding is applicable to painting operations, where unstable or inaccurate fixtures may cause surface defects from uneven paint application or movement during curing. By developing enhanced checking fixtures that secure parts firmly and maintain precise alignment, the occurrence of painting defects can be reduced, thereby improving product quality and consistency.

3.0 METHODOLOGY

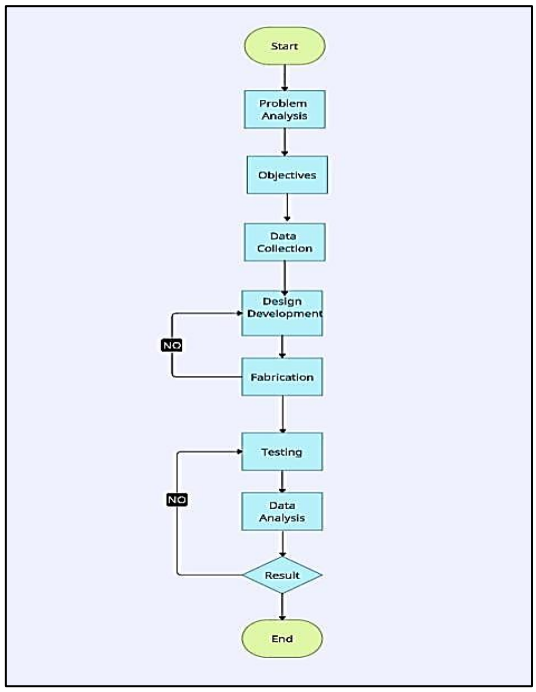

Figure 2: Flow chart of the project.

This chapter outlines the research methodology used to design, develop, and assess a checking fixture aimed at addressing issues in the painting process within Industries. The main goal is to improve fixture stability and accuracy by minimizing wobbling during painting operations. The research follows a systematic approach comprising five stages: data collection, analysis, design, prototyping, and testing. Initially, the study gathers information on the shortcomings of existing fixtures through observations, feedback from operators, and evaluation of current performance. Each phase is detailed to ensure the research is thorough, reproducible, and focused on enhancing production quality and operational efficiency.

3.1 Gemba Walk

The Gemba Walk approach plays an important role in this research by providing direct insight into the actual painting process. It helps identify real issues with fixtures, especially instability, that lead to surface defects like sagging and orange peel. Instead of relying on theories or

second-hand data, this method focuses on on-site observation to find the root causes of these problems. Additionally, structured interviews with operators who use the fixtures give useful information such as problems with fixture wobbling that may not be visible during observation, offering a fuller understanding of the process issues.

3.2 Identify Problem

The study employs the Gemba Walk approach to observe the painting process directly within its operational environment, facilitating the identification of key problems such as fixture instability that result in surface defects like sagging and orange peel. Observations point to issues including fixture wobbling and misalignment, while environmental influences such as vibration, airflow, humidity, and temperature are evaluated for their effects on fixture performance. Feedback from operators also highlights practical challenges, such as minor vibrations that compromise painting consistency. To structure the analysis, a Fishbone Diagram is utilized to categorize potential causes, and the 5 Whys method is applied to trace the root cause to the lack of a dedicated checking fixture system. In the absence of proper inspection tools, unstable fixtures remain unnoticed, leading to repeated defects. Other contributing factors include inadequate maintenance, human error, and environmental conditions. Therefore, the development and implementation of a checking fixture system is critical to enhance fixture stability, improve paint quality, and reduce defect rates on the production line.

3.2.1 Ishikawa Diagram

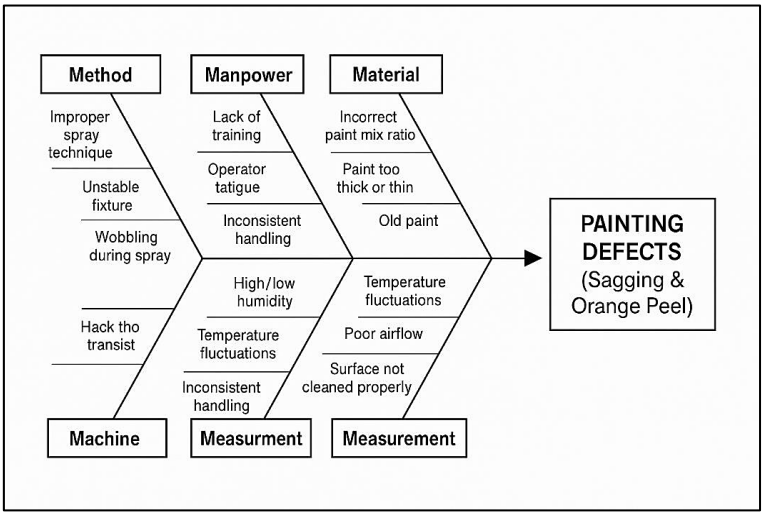

Figure 3: Ishikawa diagram

The fishbone (Ishikawa) diagram outlines the possible root causes of painting defects like sagging and orange peel, dividing them into six main categories: Method, Machine, Manpower, Material, Environment, and Measurement. In the Method section, flaws such as incorrect spray techniques, timing, or direction can result in uneven paint coverage. The Machine category addresses equipment-related problems, especially unstable or misaligned fixtures that cause irregular movement during painting. Under Manpower, factors like insufficient training, operator fatigue, and inconsistent handling are noted as human errors affecting paint quality. The Material section highlights issues with the paint itself such as improper mix ratios, unsuitable thickness, or expired materials that can compromise the final finish. Environmental elements, including temperature shifts, poor airflow, and humidity levels, can disrupt the drying

and curing process. Lastly, Measurement points to the lack of adequate inspection tools or systems, which makes it difficult to detect fixture instability or misalignment. This structured analysis helps identify and tackle the underlying causes of surface defects in the painting process more effectively.

3.2.2 5 Whys

The 5 Whys method is a problem-solving methodology that involves constantly asking "why," assisting in finding the underlying causes of a problem. (Key, n.d.)

1. Why are there defects such as sagging and orange peel on the painted goods?
   Because the fixtures used to hold the painting jig are wobbling or misaligned during the painting process.

2. Why are the fixtures wobbling or misaligned during the painting process?
   Because the fixtures are not checked and serviced properly.

3. Why are the fixtures not being check and serviced properly?
   Because there are no checking fixtures to check it.

By addressing these crucial problems through design and better testing, the project can increase fixture stability, thus minimizing errors and improving overall production quality in the painting department.

3.2.3 Root Cause

After studying the potential elements in the 5 whys, the root cause of the problem with unstable painting fixtures can be determined. (Holifahtus Sakdiyah et al., 2022; Key, n.d.).

The primary issue is the lack of a dedicated checking fixture system capable of systematically evaluating the condition and alignment of painting fixtures. This gap allows unstable or misaligned fixtures to enter manufacturing, resulting in defects like sagging and orange peel. Inadequate maintenance, operator errors, and environmental effects all contribute to the problem. By addressing these main reasons and developing a strong checking fixture system, the painting department can assure fixture stability, increase painted goods quality, and reduce defect rates.

3.3 Data Collection

Data collection is a vital step in understanding the challenges of fixture stability for this study. The goal is to collect huge and reliable data on defect of painting (sagging and orange peel), as well as the effects of fixture wobbling on production efficiency and product quality.

3.3.1 Observation

This involves directly observing the painting process to understand how the fixture performs. Watching it in action helps identify when and how defects like sagging or orange peel occur, and the specific moments the fixture becomes unstable.

Figure 4 Observation to the painting fixtures.

3.3.2 Operator Interviews and Documentation.

This study integrates feedback from operators with detailed defect tracking to evaluate the performance of fixtures in the painting process. Operators who frequently use the fixtures provide valuable insights into subtle issues like vibrations and handling difficulties that may not be evident from data alone, offering practical suggestions based on their firsthand experience (Romadhoni & Salim Dahdah, 2024). Concurrently, detailed records of defects including their types, occurrences, and locations are analyzed to understand how fixture stability impacts paint quality, especially concerning defects such as sagging and orange peel. This dual approach facilitates the identification of root causes like fixture wobbling or misalignment, guiding improvements in fixture design. Combining qualitative input with quantitative defect analysis aligns with effective process improvement strategies, as seen in applications of Six Sigma and Failure Mode and Effect Analysis in painting and coating operations (Agustin et al., 2024) Together, these methods offer a comprehensive assessment of the checking fixture's ability to reduce defects and enhance overall product quality.

3.4 Design Concept

The design phase plays a vital role in creating a checking fixture that effectively addresses alignment and stability issues during the painting process. Utilizing advanced 3D modeling software such as CATIA, the fixture is carefully developed with attention to structural durability, functional performance, and ergonomic efficiency to meet required specifications. An important aspect of the design includes minimizing circular run-out deviation in rotating components which can cause misalignment, uneven paint distribution, and defects like orange peel. Controlling circular run-out ensures secure part positioning, reduces vibration, and promotes smooth, uniform paint application.

3.5 Sketching

The process starts with creating several hand-drawn design concepts that visually represent possible fixture solutions, focusing on structure, function, and integration with the painting jig. Each design is then evaluated based on key criteria such as stability, ease of use, system compatibility, and ability to detect and correct misalignments. After careful review, the best design is selected for further development and improvement.

3.5.1 Design Detailing.

The design phase is crucial for developing a reliable checking fixture that addresses issues of misalignment and instability during the painting process. In this stage, advanced 3D modeling tools like CATIA are utilized to produce accurate and detailed fixture designs. The focus is on

optimizing the fixture's structural integrity, functionality, and ergonomic features to ensure it performs effectively and meets the required standards.

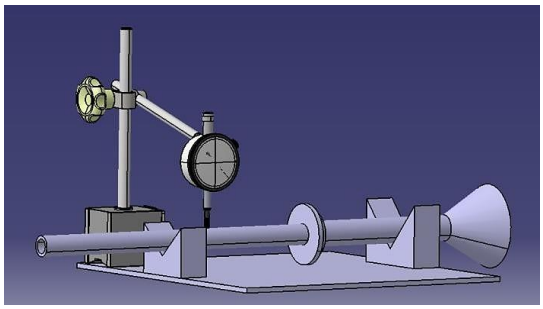

Figure 5: Design 1

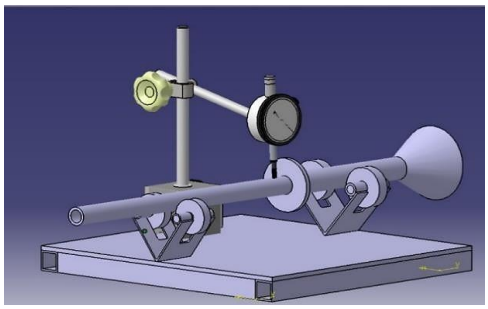

Figure 6: Design 2

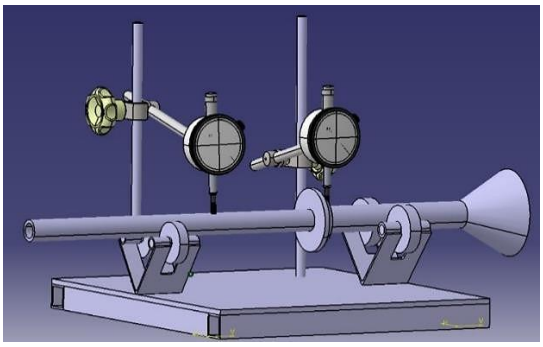

Figure 7: Design 3

3.6 PUGH Method

Table 1PUGH Matrix Table.

		Weight	Design 1	Design 2	Design 3	Design 1 Weight	Design 2 Weight	Design 3 Weight
1	Accuracy	9	8	8	6	72	72	54
2	Ease of Use	6	3	5	6	18	30	36
3	Friction / Movement	6	-1	5	5	-6	30	30
4	Suitability	9	4	9	8	36	81	72
5	Costs	5	5	3	4	25	15	20
6	Score					145	228	212

The Pugh method, or decision matrix approach, is essential to this project as it offers a structured way to evaluate and choose the best design from several options. When designing and refining checking fixtures, this method allows for the comparison of different designs, materials, or setups based on important factors like stability, precision, ease of use, cost, and manufacturability. By weighting these factors and scoring each alternative, the Pugh method supports objective, data-driven choices, reducing bias and improving the chances of selecting

an effective and reliable fixture design. Among the designs, Design 2 was selected as the best fit because it offered an excellent combination of precise performance, smooth operation due to the use of bearings, ease of handling, and affordability.

Based on this comparative analysis, **Design 2** emerged as the optimal choice due to its balanced integration of bearings and magnetic gauges, resulting in superior stability, inspection accuracy, and defect detection capabilities. This combination not only minimized friction but also facilitated comprehensive monitoring, aligning with the project's objective of enhancing quality control in painting and inspection processes.

3.7 Crucial Components.

The table above outlines the key components essential for the proper function and effectiveness of the checking fixtures. These items are selected to ensure accurate measurement, reliable performance, and smooth operation during inspection. Each component plays a vital role in maintaining fixture stability, alignment, and precision. Their inclusion helps streamline the inspection process and ensures consistent, high-quality results, highlighting their importance in the overall performance of the checking fixtures.

Table 2: Crucial Components.

	COMPONENT	FUNCTION	PICTURE
1	Dial Gauge	To determine where the unstable spots is at the fixture.	
2	Bearing	To make sure the fixtures turn smoothly.	

3.8 Material Selection.

Material selection focuses on choosing materials that can withstand mechanical stress, environmental factors such as paint chemicals and heat, and operational wear. For this project, key components and the fixture frame should use strong, corrosion-resistant materials like stainless steel, aluminum alloys, or high-strength plastics. These materials offer the necessary stability while remaining lightweight for easier handling and adjustment during testing.

3.9 Fabrication

After material selection, the design is transformed into a physical fixture during the fabrication stage. Depending on the design's complexity and chosen materials, this may involve precision

methods such as CNC machining, laser cutting, or welding process. Throughout fabrication, close monitoring is required to ensure precise assembly and allow for adjustments or calibration to eliminate wobbling and ensure stability.

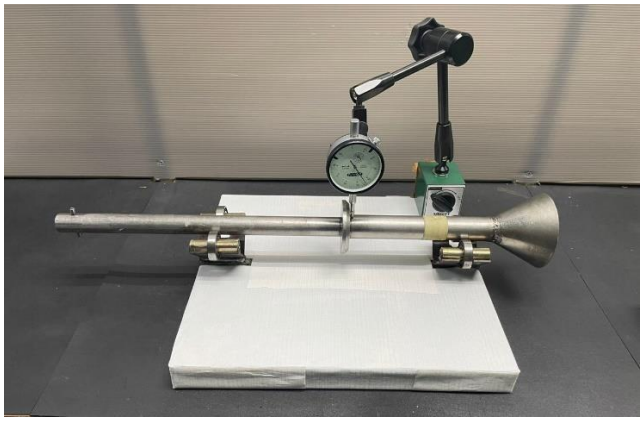

Figure 8: The checking fixtures

3.10 Product Testing

Testing is essential to verify that the checking fixture performs as intended. This involves evaluating the fixture under actual conditions in the painting department to assess its ability to detect instability and wobbling. Tests simulate the range of forces the fixture may face, including vibration, weight shifts, and temperature changes. Precise measurements ensure the fixture can identify even small misalignments. Any issues found during testing lead to design, material, or assembly adjustments. This iterative process ensures the final fixture is reliable, durable, and effective in minimizing defects during painting.

4.0 RESULTS AND DISCUSSION

This section outlines the findings from the issue analysis and the selection of the final design using the Pugh method and weighting decision method. Guler and Petrisor (2021) highlighted how the Pugh method assists small design teams in systematically assessing design alternatives based on factors such as Ease of Use, Accuracy, Cost, Material Usage, Setup Time, Ergonomics, and Safety (Guler & Petrisor, 2021). Following a comprehensive evaluation of potential solutions, the design that best fulfilled these criteria was selected as the final design. This methodical, data-driven approach ensured a fair and objective selection process, aligning the chosen solution with project objectives.

4.1 Defect Rate Data

Fixture wobbling in painting processes is primarily caused by inadequate fixture design, structural wear, and improper alignment. Insufficient rigidity or weak locking mechanisms can result in unintended movements, leading to paint defects such as sagging and orange peel. Over time, wear and tear further compromise fixture stability, increasing susceptibility to wobbling. Data collected over three months before implementing the checking fixture revealed that sagging defects consistently outnumbered orange peel defects. As shown in figure 4, In October, sagging defects reached 7,000 occurrences, while orange peel defects were recorded at 1,000. By December, sagging defects dropped to 5,000, while orange peel defects stabilized at 2,000.

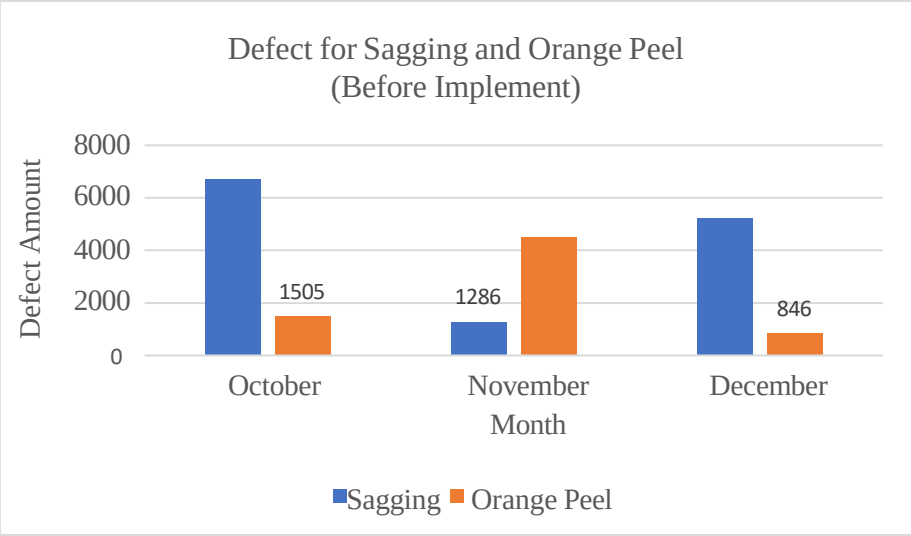

Figure 9 Defect for Sagging and Orange Peel (Before Implement)

The comparative data illustrate that fixture instability has a greater impact on sagging than on orange peel defects, with the latter showing a gradual increase over time. Implementing the checking fixture is expected to address these issues by enhancing fixture stability and reducing wobbling. To assess its effectiveness, baseline defect rates are compared with post-implementation data, visually presented in bar charts to highlight changes in defect occurrences and verify improvements in painting consistency.

The Gemba Walk conducted in the painting department revealed key areas of fixture instability that significantly contribute to defects like sagging and orange peel. The observational analysis identified three critical sections as particularly susceptible to instability. The central shaft exhibited the most pronounced wobbling, primarily due to lateral displacement caused by insufficient rigidity and inadequate support. The shaft's slender structure and length increased its susceptibility to bending and oscillation, especially under dynamic loading during the painting process.

4.2 Defect Rates Data After Implementation of Checking Fixtures

The graph on figure 10 below shows a clear improvement in paint quality after the introduction of checking fixtures, with both sagging and orange peel defects decreasing steadily over time. This downward trend reflects the effectiveness of the fixtures in stabilizing components during the painting process, which helps ensure more uniform coating application. The consistent drop in defect rates suggests that the fixtures successfully addressed earlier issues related to misalignment and wobbling. In general, the results highlight how proper fixture implementation can significantly reduce paint-related defects and contribute to a more controlled and efficient production process.

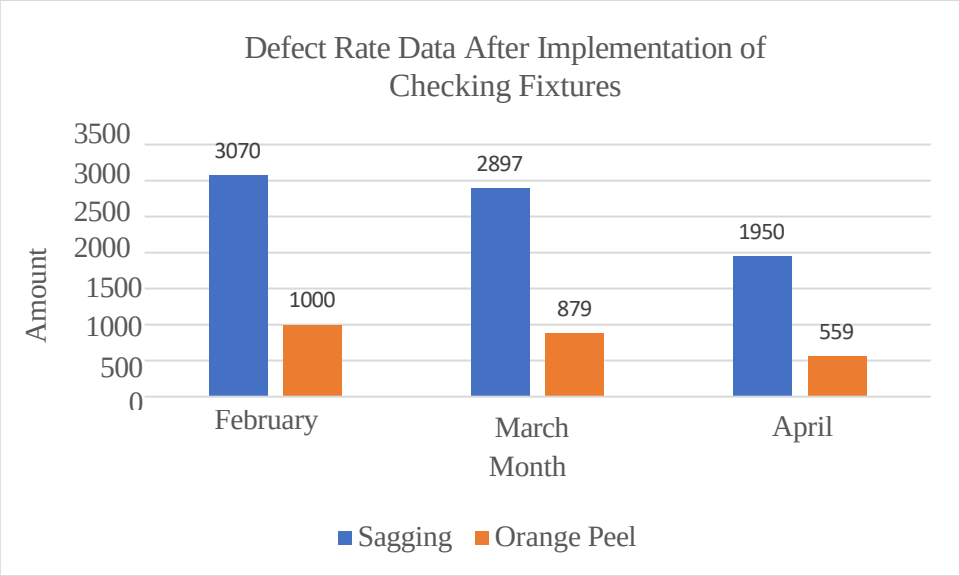

Figure 10: Graft of defect rate data after checking fixtures use.

4.3 Comparison

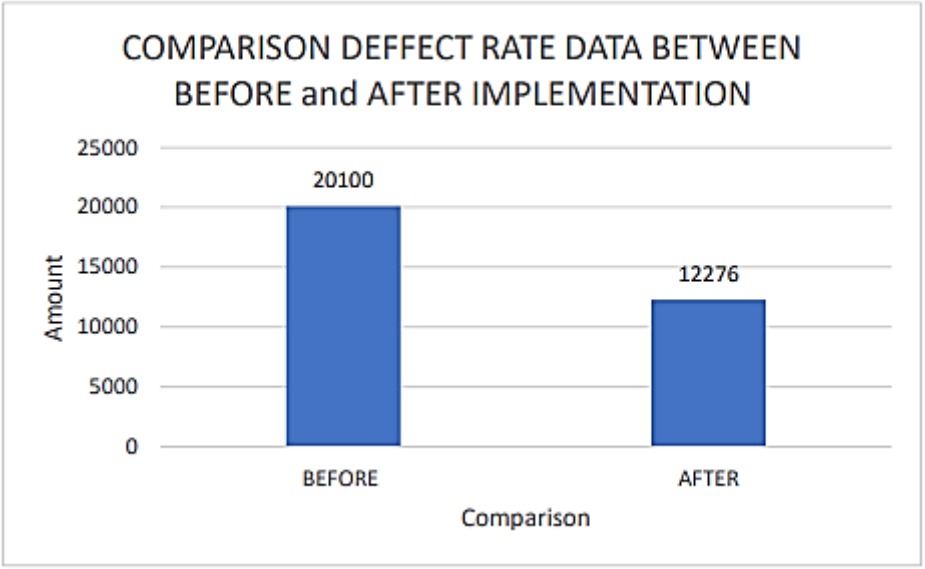

Figure 11: Graft comparison of before and after.

The figure 11 shows a graph improvement in product quality after the introduction of checking fixtures. Initially, the number of recorded defects was 20,100, but this figure dropped to 12,276 following the implementation. This decrease of 7,824 defects indicates that the checking fixtures played an important role in improving accuracy and minimizing production errors. Overall, the data supports that the fixtures had a positive impact on the manufacturing process. To calculate the percentage reduction in sagging after the implementation of the checking fixture, we can use the formula:

Reduction Amount: Percentage Reduction:

$$20{,}100 - 12{,}276 = 7{,}824$$

$$\frac{7{,}824}{20{,}100} \times 100 = 38.92\%$$

This represents a 38.92% reduction, highlighting the effectiveness of the checking fixtures in minimizing common defects such as sagging and orange peel. The improvement indicates that the checking fixtures played a key role in identifying and preventing errors more efficiently during the painting process.

5.0 CONCLUSION

The research successfully demonstrated that unstable painting fixtures are a primary cause of surface defects such as sagging and orange peel in automotive production. Through on-site analysis and structured problem-solving methods, a checking fixture was designed and implemented to address these issues. The new fixture significantly improved stability during the painting process, resulting in a measurable reduction in defect rates. The 38.92% drop in sagging defects highlights the fixture's effectiveness in enhancing product quality, reducing rework, and improving operational efficiency. This project reinforces the importance of proper fixture inspection systems and provides a replicable approach for quality improvement in similar manufacturing environments.

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Design and Development of a Fixture for Assembly Bezel Air Vent Using Pugh Matrix Analysis for Design Enhancement

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ABSTRACT

This study investigates the development of a fixture to improve the assembly process of Bezel Air Vents., where the manual method currently used poses challenges such as mishandling, and extended assembly time. The main aim is to enhance product quality and reduce cycle time through the implementation of a precision-based fixture. The research is significant as it addresses common inefficiencies in manual assembly processes within the plastics manufacturing industry. A fixture design was developed using CATIA V5 software and evaluated through multiple design iterations. Stainless Steel (Grade 304 or 316) was selected for its mechanical properties and suitability in industrial environments. Three concepts were proposed and analyzed using the Pugh Matrix to determine the most effective design based on assembly performance and ease of use. A one-week trial revealed that the new fixture reduced the average assembly time from 23 seconds to 19 seconds per unit and enabled greater output consistency across operators. Additionally, feedback from operators highlighted improvements in ergonomics and reduced fatigue. The study concludes that the fixture offers a reliable, efficient, and operator-friendly solution for the assembly of plastic components. It is recommended for broader adoption in similar production environments to improve both throughput and assembly quality.

Keywords: fixture design, bezel air vent, CATIA V5, assembly optimization, cycle time reduction.

1.0 INTRODUCTION

This chapter introduces the research aimed at improving the assembly process of Bezel Air Vent using the fixture at Company A. The main objective of the research is to streamline the assembly process by designing the fixture to increase efficiency and speed. The new design focuses on enabling the alignment and assembly of all components of the Bezel Air Vent with just a single pressing motion. The concept centres around a top-base pressing mechanism to simplify the assembly process and reduce errors and time wasted during production.

Fixture have always played a critical role in manufacturing, especially in optimizing workflows, ensuring consistency, and minimizing human errors (Carr Lane Manufacturing Co., n.d.; Pandit & Pandit, 2023). By improving precision and handling, jigs contribute to overall productivity and product quality (Ansini Ltd., 2019). This chapter will discuss the history and significance of jigs in manufacturing, focusing on their role in achieving precision and efficiency.

The review covers important factors such as alignment accuracy, material handling, and fitment techniques, all of which are essential for a successful assembly process (Britannica, n.d.; Xometry Europe GmbH, n.d.). The effectiveness of the proposed fixture design will be evaluated through methods like durability testing, precision checks, and cycle time analysis. Material selection for the design will also be considered, focusing on durability and

machinability (LEADRP, 2024; Uno Factory, n.d.).

This introduction sets the stage for the study, aligning the research objectives with the broader aim of improving efficiency, minimizing defects, and optimizing production processes at Company A. The innovation in design is expected to offer valuable insights into enhancing assembly operations and addressing modern manufacturing challenges.

1.1 Literature Review

Company A is a leading manufacturer specializing in plastic components for the automotive industry. With a strong reputation for delivering high-quality products, the company has established itself as a trusted partner for major automotive brands, including Company B. Its extensive capabilities include injection moulding, assembly, and research and development, ensuring that it meets the ever-evolving demands of the automotive sector.

The Business and Development Design Department plays a critical role in driving innovation within the company. This department is responsible for conceptualizing, developing, and refining designs for various automotive components. It bridges the gap between customer requirements and manufacturing capabilities, ensuring that products are not only functional but also cost-effective and efficient to produce. The department also spearheads projects aimed at improving assembly processes and enhancing product quality.

One of the prominent projects undertaken by Azman Hamzah Plastik Sdn. Bhd. is the production of the Bezel Air Vent for Perodua vehicles. The Bezel Air Vent is a crucial component in vehicle dashboards, requiring precision in both design and assembly. Meeting stringent customer specifications while optimizing production efficiency is essential for the success of this project.
In this context, the current study focuses on designing and improving the fixture used in the Bezel Air Vent assembly process. The existing assembly method, which involves pressing the Air Vent into the Bezel slot, is time-consuming and prone to inefficiencies. By developing a new fixture that enables a single pressing motion to assemble all parts, the project aims to streamline the assembly line, reduce production time, and improve overall product quality.

This study reflects Azman Hamzah Plastik Sdn.Bhd commitment to continuous improvement and its dedication to maintaining a competitive edge in the automotive industry. Through innovative design and process optimization, the company strives to meet and exceed customer expectations while contributing to the advancement of manufacturing technology.

1.2 Problem Statement

At Company A the Bezel Air Vent assembly process involves manual handling, which presents a potential risk of scratches or defects if operators mishandle the part or accidentally drop it during installation. Although no damage has been recorded yet, operator error or carelessness could lead to quality issues.

Additionally, the current single step pressing process still lacks a proper fixture, which affects assembly precision and slows down the cycle time. This limits production efficiency and could impact the ability to meet customer demand. A dedicated fixture is needed to prevent part damage and reduce assembly time, ensuring both safety and productivity on the line.

1.3 Objective

- To optimize the assembly process by replacing the current process and go on using fixtures, reducing cycle times, increasing productivity, and improving overall operational efficiency.

2.0 METHODOLOGY

The project methodology outlines the structured approach used to address the challenges associated with design fixture in the assembly process. This chapter provides a comprehensive description of the methods that will guide the research from initiation to completion, ensuring a systematic and effective investigation. Initially, a flowchart will be developed to illustrate the step-by-step progression of the project, utilizing the PDCA (Plan-Do-Check-Act) methodology for continuous improvement and problem-solving. To identify specific issues with the current assembly process, a fishbone diagram will be employed, allowing for a systematic analysis of potential root causes in a clear and organized manner. Furthermore, a survey or questionnaire will be distributed among factory workers to gather feedback on the current assembly process and assess the level of support for the proposed improvements. This will provide valuable insights into the practical concerns and preferences of those directly involved in the assembly process. Finally, the Pugh matrix will be used to conduct a detailed comparison between the assemble without using fixture and after using fixture, evaluating multiple criteria such as efficiency, cost, ease of use, and overall performance to select the most optimized solution. This methodology ensures a thorough, data-driven approach to addressing the challenges of fixture design, aligning with both technical requirements and user feedback. This paper focuses on the implementation of the PDCA methodology, which stands for Plan-Do-Check-Act. The research follows a systematic process that begins with planning, followed by doing, checking, and finally, acting on the findings. Figure 3.1 illustrates the flowchart that will guide the progression of the project, ensuring a structured approach to problem-solving and continuous improvement throughout the research.

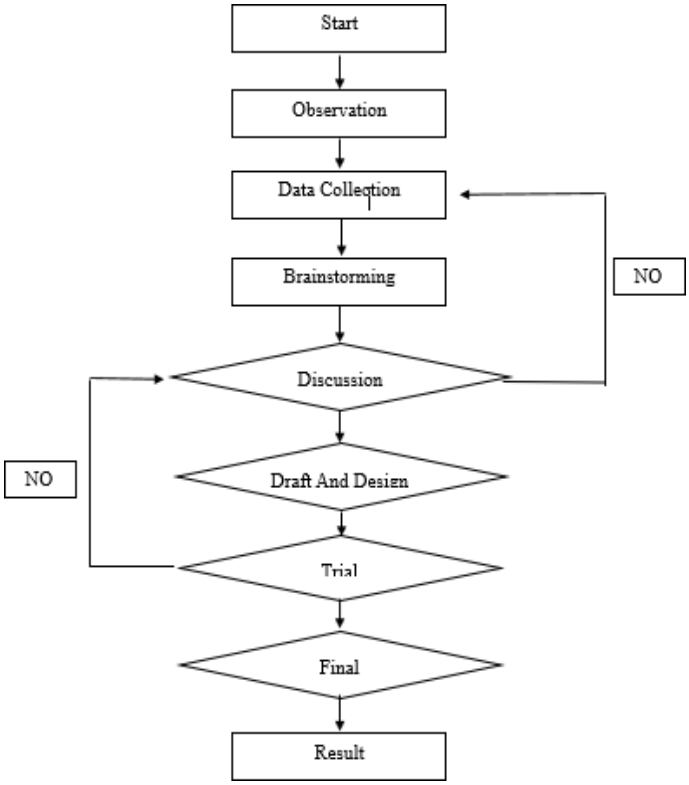

Figure 1: Flow Chart

3.0 RESULTS AND DISCUSSION

The purpose of this paper is to analyse the effectiveness of a custom-designed fixture in improving the assembly process of an air vent to its bezel. The fixture was conceptualized and developed to address challenges in alignment, consistency, and operator efficiency during the assembly process. By minimizing manual effort and ensuring precise positioning, the fixture design contributes to achieving higher quality standards and reducing cycle times. After fabricating the new fixture, the trial process must be done at assembly line.

3.1 Concept Design

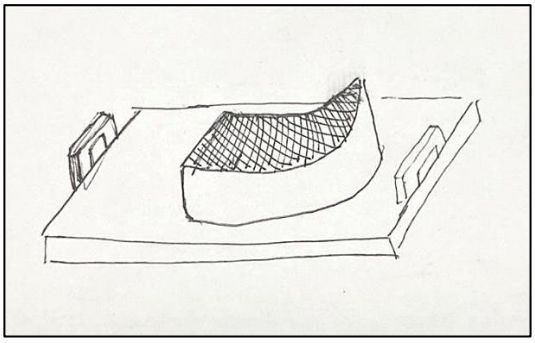

Figure 2: Design 1

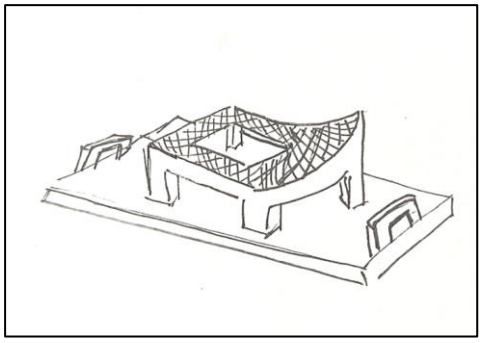

Figure 3: Design 2

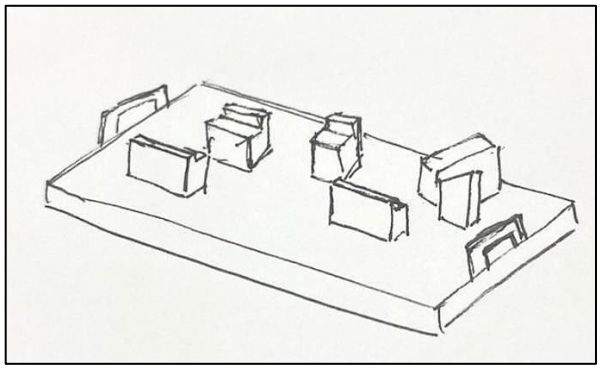

Figure 4: Design 3

3.2 Design Selection

The most suitable fixture design for the bezel air vent assembly was chosen based on four key factors: safety, cost, weight, and simplicity. These criteria were used to find a design that would improve the assembly process, reduce time, and protect the parts from damage. Among the three designs considered, Design 3 stood out as the best overall, scoring the highest in all categories.

In terms of safety, Design 3 provides strong stability by firmly securing the bezel and air vent during assembly. This reduces movement, lowers the risk of operator errors, and ensures consistent quality. It also scored highest for cost efficiency due to its simple structure and low material use, which helps reduce both production time and cost. When it comes to weight, Design 3 is the lightest, making it easier to handle and reducing strain on workers. Its lightweight nature also improves the overall ease of operation.

Simplicity was another strength of Design 3. Its straightforward design makes it user-friendly and easy to maintain, allowing operators to work quickly and efficiently while minimizing the risk of scratches on the parts. Overall, Design 3 proved to be the most effective choice for this project. It supports a faster, safer, and more efficient assembly process, meeting the goals of quality and productivity.

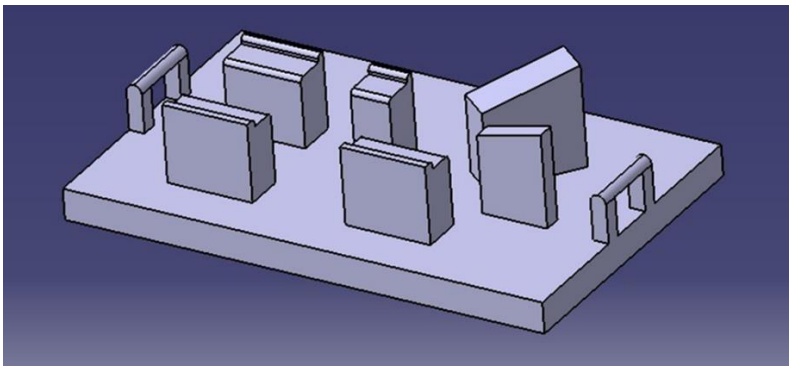

Figure 5: Design 3 in Catia V5

3.3 Result Data Collection

3.3.1 Pugh Metrix

Table 1: Pugh Metrix

Criteria	Design 1	Design 2	Design 3
Safety	3	4	5
Cost	3	4	5
Weight	3	3	5
Simplicity	2	4	5
Total	2.9	3.7	5.0

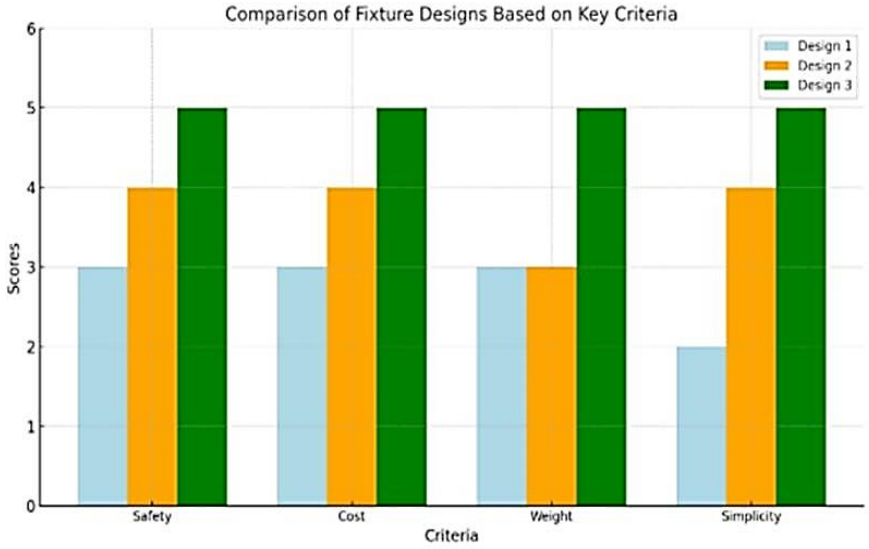

Figure 6: Comparison Pugh Metrix for Type of Design

3.3.2 Result Cycle Time Before and After

Table 2: Step Assembly Bezel Air Vent

Step No.	Step Description	Cycle time (s)	Reason for longer time	inspection
1	Align air vent to bezel manually	5	Match air vent position to bezel clips	Visual alignment check
2	Snap first clip	3	Snap first clip into position	Audible/visual check
3	Snap second clip	3	Press the second clip firmly	Audible / visual check
4	Snap third clip	3	Press the third clip firmly	Audible/visual check
5	Snap fourth clip	3	Snap the fourth clip into position	Audible/ visual check
6	Snap fifth clip	3	Snap the final clip into place	Audible /visual check
7	Perform functional test	3	Check all clips are secure and test functionality	Ensure clips are tight
Total	23			

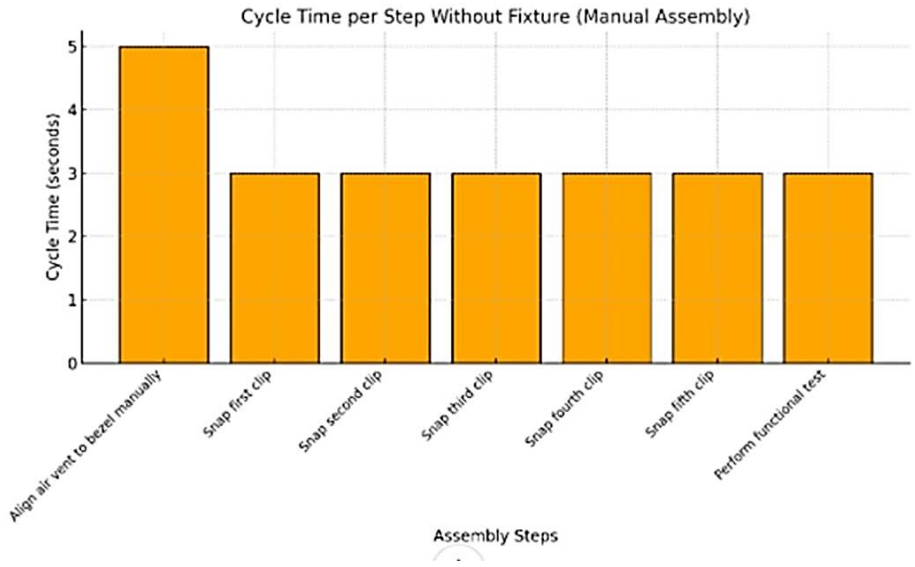

Figure 7: Statistics before using Fixture

Table 3: Step Assembly bezel Air Vent after using Fixture

Step No.	Step Description	Cycle time (s)	Reason for Fixture	inspection
1	Place bezel into fixture	3	Ensures correct positioning and stability	Visual check for alignment
2	Align air vent to bezel using fixture	3	Fixture guides alignment, reducing manual effort	Confirm alignment visually
3	Snap first and second clips	4	Fixture secures the bezel for precise clipping	Audible snap for secure fit
4	Snap third and fourth clips	4	Reduce assembly time by stabilizing the parts	Audible snap for secure fit
5	Snap fifth clip	2	Fixture holds part steady for easy snapping	Audible snap for secure fit
6	Perform functional test	3	Ensures smooth vent movement post-assembly	Check vent operation
Total	19			

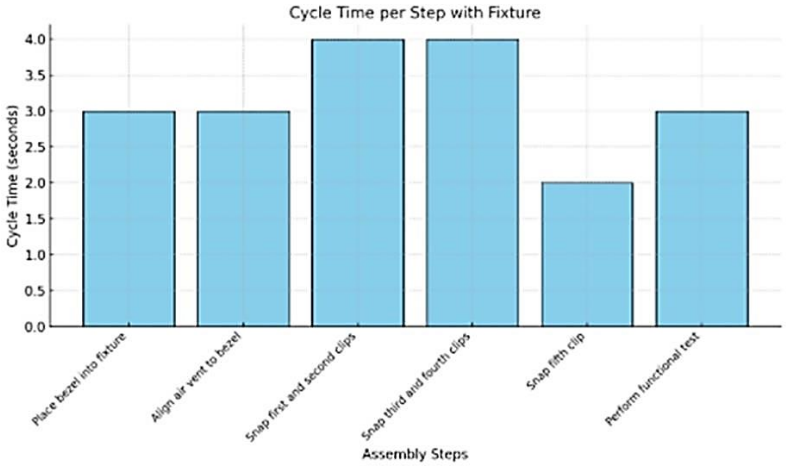

Figure 8: Statistics after using Fixture

3.3.3 Percent Improvement

Introducing the fixture into the assembly process led to a big improvement in efficiency, reducing the total cycle time from 23 seconds to 19 seconds—a 17.39% improvement. This change made the assembly faster and more productive. The fixture helped align the parts better, which reduced the need for manual adjustments that were slow and often inconsistent. With the fixture, the operator could

position and secure the clips more quickly and accurately, avoiding delays caused by misalignment. It also made the process easier on the operator by reducing physical effort, which helped prevent fatigue and ensured more consistent performance. Overall, the fixture played an important role in improving both the speed and quality of the assembly process, showing how even small time savings can make a big difference in large-scale production.

$$\text{Percentage Improvement} = \frac{\text{Cycle Time Before - Cycle Time After}}{\text{Cycle Time Before}} \times 100$$

$$\text{Percentage Improvement} = \frac{23 - 19}{23} \times 100 = 17.39\%$$

3.3.4 Comparison Cycle Time in 1 Week (Trial Assembly)

During a one-week trial for assembling the bezel air vent, a clear comparison was made between manual assembly and using a fixture. The results showed that using the fixture greatly improved both speed and consistency. Manual assembly took an average of 23 seconds per unit, while fixture-assisted assembly reduced this to 19 seconds. Over an 8-hour shift, this meant workers could assemble over 15% more units. The fixture also improved the quality of the assembly by keeping the parts aligned and clipped securely each time. Operators reported feeling less tired and strained thanks to the fixture's ergonomic design, which helped them stay efficient throughout the day. Overall, the trial showed that using the fixture saved time, improved product quality, and made the assembly process easier and more reliable.

Table 4: 1 Week Trial Comparison

Metric	Before Using Fixture	After Using Fixture
Cycle time (s)	23	19
Units assembled per day	50	50
Daily time required (hours)	$\frac{250 \times 23}{3600} \approx 1.6$ hours	$\frac{250 \times 19}{3600} \approx 1.3$ hours
Weekly total units	350	350
Weekly time required (hours)	1.6 x 7 = 11.2 hours	1.3 x 7 = 9.1 hours

Although the number of units assembled per day stayed the same at 250, using the fixture made it much faster to reach that goal. Before the fixture, it took about 1.6 hours a day (11.2 hours a week) to assemble 250 units. After adding the fixture, it only took 1.3 hours a day (9.1 hours a week), saving 2.1 hours each week. This saved time can be used for other tasks or to increase production if needed.

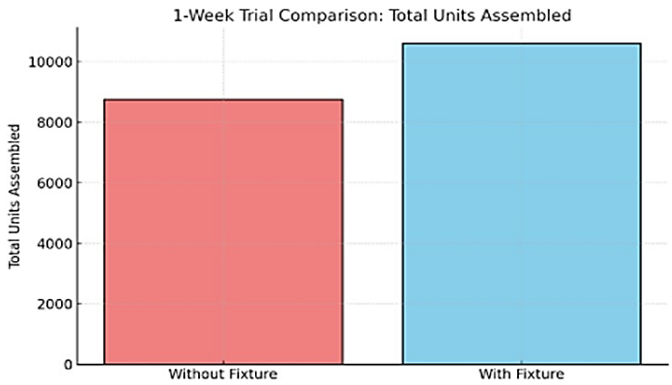

Figure 9: Estimated timing of cycling after BEX Procedure

3.3.5 Questionnaire

Table 5: Questionnaire Result

Bil	Question	Yes	No
1	Do you agree to use the fixture for the assembly line air vent to bezel?	7	3
2	In your opinion, is the process relevant or not after using this fixture?	8	2
3	Can the cycle time improve with this fixture?	9	1
4	Can this process using fixture help operator?	8	2
5	Can the output of assembling the bezel air vent improve?	7	3
Total		39	11

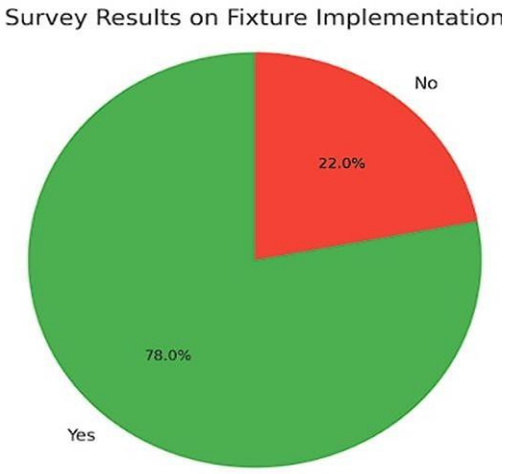

Figure 10: Pie Chart

The pie chart shows that 78% of operators said "Yes" to using the fixture, showing strong support for it on the assembly line. Most operators felt it helped improve the process by reducing cycle time, making the work easier, and improving the quality of the final product. Only 22% said "No," which means a small number did not see much improvement or had concerns. Overall, the feedback shows that the fixture has made a positive difference, supporting the decision to use it more widely in the assembly process.

4.0 CONCLUSION

In conclusion, the implementation of the designed fixture successfully met the objectives of improving the bezel air vent assembly process. Design 3, chosen based on its performance across safety, cost, weight, and simplicity, proved to be the most effective and practical solution. The fixture led to a notable reduction in cycle time, improved assembly consistency, enhanced ergonomics, and better overall operator experience.

The fixture not only optimized production efficiency but also positively impacted product quality and worker satisfaction. The time savings achieved can be strategically utilized for other value-added tasks or expanded production goals. Operator feedback further validated the effectiveness and practicality of the fixture, supporting its adoption as a permanent tool in the assembly line.

Overall, this study demonstrates that a well-designed fixture can have a significant positive impact on repetitive manufacturing processes. Future work could explore additional fixture enhancements, automation possibilities, or scalability to other assembly tasks within the production environment.

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Design and Development of a Fixture to Enhance the Efficiency of Seal-Radiator Assembly in the Production Line

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ABSTRACT

This paper presents the design and development of a customized fixture for the seal sub- assembly radiator on the assembly line to address accuracy and consistency challenges in the final manufacturing phase. In response to growing demand for the car components, Company X aims to propose an assembly line with the fixture ensures precise sponge alignment during assembly, reducing rejection rates, improving product quality, and enhancing customer satisfaction. Using CATIA V5, operator feedback, customer complaint analysis, the project identifies root causes and collaborates with engineering and quality teams to refine the design. Prototype and testing are conducted to ensure performance. Expected outcomes include simplified assembly, fewer defects, reduced production time, lower costs, and improved consistency. Ultimately, the project enhances production efficiency and product quality, increasing customer satisfaction and meeting evolving automotive industry demands.

Keywords: customized fixture design, assembly line accuracy, manufacturing consistency, defect reduction, quality control, product quality enhancement.

1.0 INTRODUCTION

As the automobile business is highly competitive, maintaining quality and safety requirements depends on component precision and accuracy. The seal sub-assy radiator, which is a component of the car's It has been particularly difficult to attain the required precision and uniformity because there isn't a specific fixture for applying the sponge during assembly. Despite advancements in manufacturing, there provide a thorough analysis of the most recent advancements in fixture manufacturing methods, technologies, and their numerous applications in different sectors. This study intends to reduce rejection rates, time-consuming, and overall cost of production also improve the quality of final products that are provided to clients by designing and developing an assembly fixture to evaluate and improve the accuracy of seal sub-assy for radiator components.

1.1 Problem Statement

There is much pressure on the company to boost production without compromising on quality due to the high demand for radiator seal sub-assy. The company is coming under pressure to produce larger quantities whilst maintaining strict quality requirements. One of the key challenges in the assembly of the radiator's seal sub-assy is the absence of fixture for applying sponge, which causes a high level of defects, consumes a lot of time, and is costly to the company, all these aspects worsen the productive activity. It has to do with the ability of the company to meet client expectations and the quality of its products. Without the fixture, the operation will have to be adjusted by hand all the time, without any accuracy and evenness, which increases the cost and reduces efficiency.

As shown in Figures 1, the seal sub-assy for radiator assembly is on a manual alignment with no committed fixture. As is indicated in figure 2 we have run 30 pieces trial, result shown the rate of rejection/defect rate is significantly increasing without a fixture. The lack of fixture is a serious problem in the assembly line of seal sub-assy for radiator components. Inconsistent component relationships and unnecessary resource utilization have been the consequences of this weakness. Heightened costs of production and reduced general productivity are all the effects of such inefficiencies that have adverse effects on the ability of the business to meet the needs of the clients and remain competitive in the market.

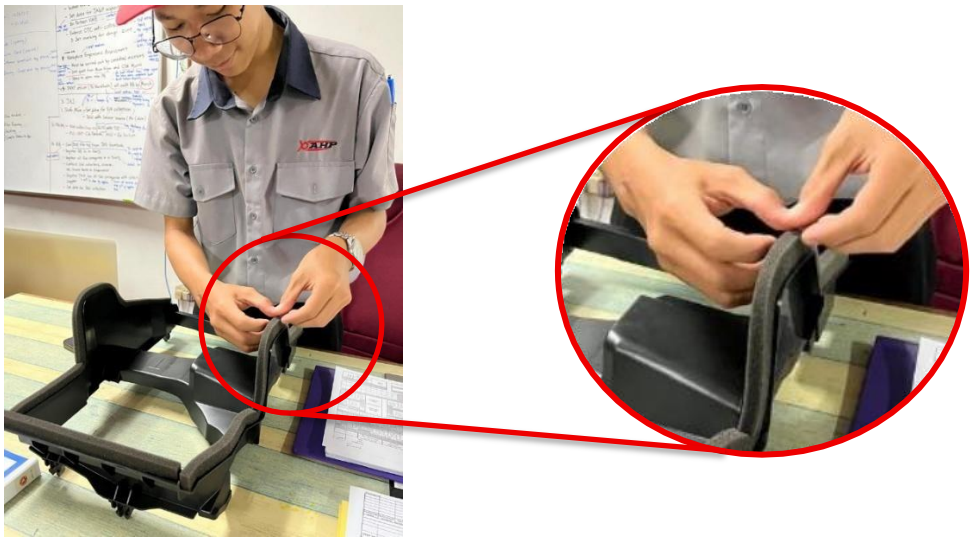

Figure 1: Applying sponge without fixture

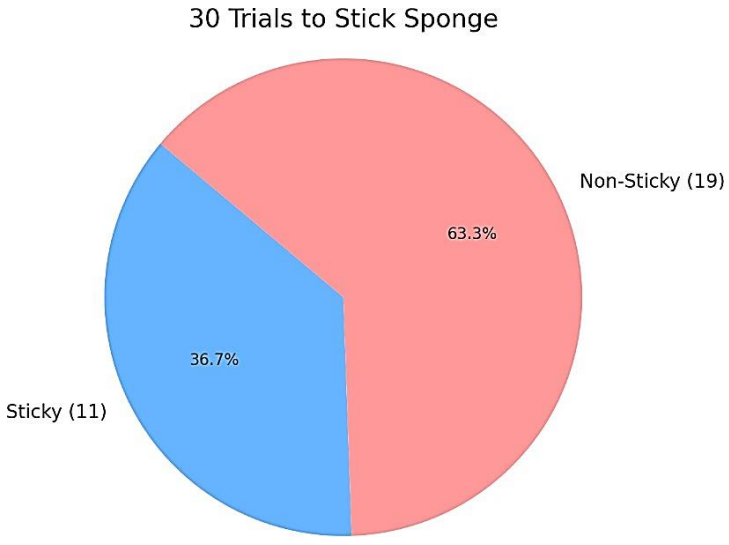

Figure 2: Data defect from 30pcs trial

1.2 Objective

The primary objective of this research is to propose an assembly line with the fixture to ensure precise alignment of sponge during the assembly process. The focus is on reducing the rejection rates of finished goods, thereby improving overall product quality and ensuring customer satisfaction.

1.3 Literature review

1.3.1 Jig and fixture Design in Manufacturing

Industrial jigs and fixture are essential in manufacturing for improving accuracy and standardizing machining processes. According to Okpala and Okechukwu, jigs and fixture enable the production of precise, interchangeable, and cost-effective components by reducing tool change and cycle times, while also decreasing product variation, inspection needs, and enhancing operator safety. Made from strong yet lightweight materials, jigs and fixture provide consistent results in operations like drilling without complex setups. They increase production efficiency by securely holding components and guiding tools, which reduces idle time and supports automation, allowing semi-skilled operators to achieve precision. This aligns with lean manufacturing principles by minimizing waste, cutting rework, and speeding production cycles, thereby boosting productivity and lowering costs (Chikwendu Okpala & Okechukwu, 2015). Kumar emphasizes that modular jig systems further reduce takt time and increase throughput by machining multiple parts simultaneously. Incorporating continuous improvement and frameworks like Design for Six Sigma (DFSS) optimizes jig performance. These modular systems offer flexibility, scalability, and ergonomic designs based on operator feedback, resulting in over 30% output increases and significant cost savings, highlighting the importance of innovative jig designs for sustained manufacturing excellence (Kumar, n.d.).

1.3.2 Importance Fixture in Precision Assembly

Fixtures are now used in precision projects to make sure the quality of a product is the same by locking the components in the correct positions. Radhwan et al. underline the significance of focusing on ergonomics, the strength of each material and fixture clamping when designing a fixture for enhanced work processes and results (Radhwan et al., 2019). Semi-automatic fixtures are more efficient and have fewer mistakes thanks to using brainstorming and ergonomic methods like those found in their e-ring insertion jig. According to Fiedler et al., the system they propose follows the 3-2-1 principle and relies on flexible, sensor-backed and computer-enabled fixtures for improved accuracy (Fiedler et al., 2024).

1.3.3 Pugh method

The Pugh Method is a widely used quantitative tool in manufacturing for improving product and process designs. Zhu et al. combined it with Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) to prioritize user requirements and evaluate design options, reducing subjectivity in decision-making (Zhu et al., 2022). Guler and Petrisor highlighted its effectiveness in boosting productivity in small design teams by systematically comparing and refining design choices based on criteria (Guler & Petrisor, 2021). The Pugh Matrix enhances decision accuracy, fosters creativity, and minimizes bias by guiding comparisons through a structured process (Barr, 2023). Overall, the Pugh Matrix is a valuable tool for innovation and competitive advantage in modern manufacturing.

2.0 METHODOLOGY

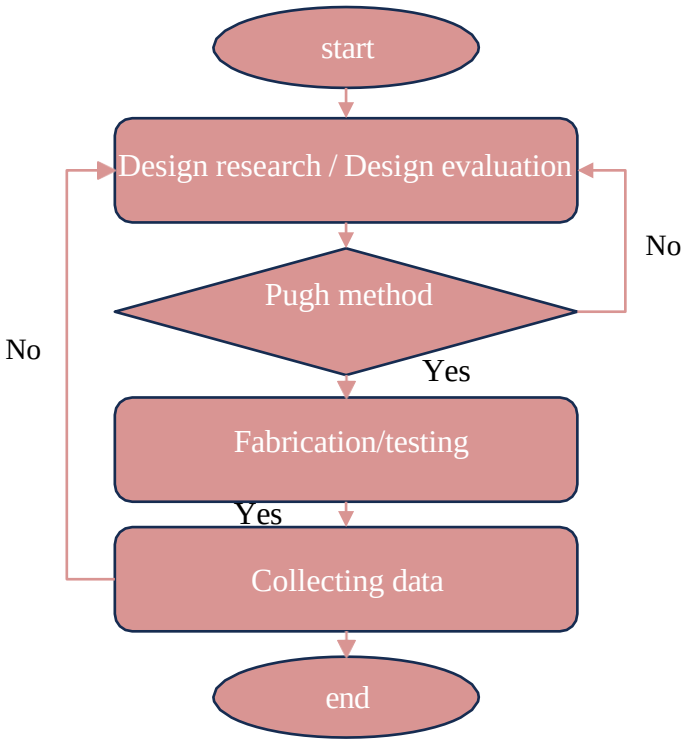

Figure 3: Flow chart

2.1 Design Research

Catia V5 is a powerful CAD tool which has been selected for its accuracy as well as detailed modeling. Catia V5 allows creating, modifying, and verifying design for fixture using detailed 3D visualization and analysis providing accuracy of measurements, allowances and functionality. Such a systematic approach is in line with best practices of the industry to support manufacturing, testing, and implementation. Additionally, Catia V5 can increase design quality by increasing its precision and eliminating errors and smoothen communication between engineers and manufacturers through integrated design data and documentation. By enhancing the accuracy as well as errors, this CAD program improves the quality of designs. It also enhances communication because the engineers and manufacturers will have a source of truth.

2.2 Design Evaluation

The design iterations Design 1, Design 2, and Design 3 were intensively compared with the approach considering such factors as weight, safety, ergonomics, speed and simplicity. According to these requirements, the ability of each design option to meet was identified and scores were allocated accordingly.

Amongst the vital criterions taken into consideration when choosing the most ideal designs for the seal sub-assy for radiator fixture, functionality of products, product manufacturability, cost-effectiveness and user-friendliness were some of the vital points considered. Three conceptual designs were compared, in regard to the sacrifices to make the assembly line more efficient, accurate, and not dangerous to operators. The capability of holding components securely by each design, adjustability, and capability of increasing the impact of productivity on the whole system were all the objects of study. Comparing the designs in depth, the top three designs were selected for further development and assessment. The above chosen concepts are

presented in Figure 4, Figure 5 and Figure 6.

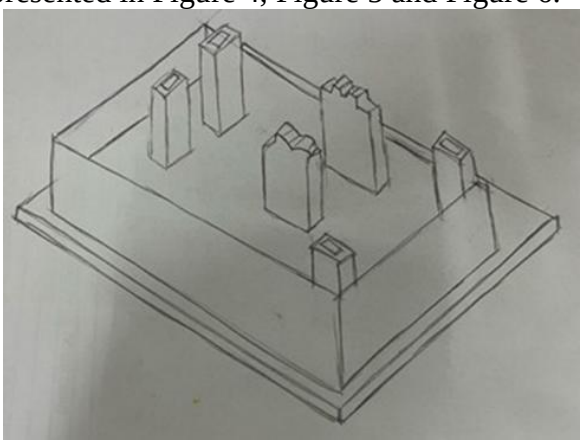

Figure 4: Design 1

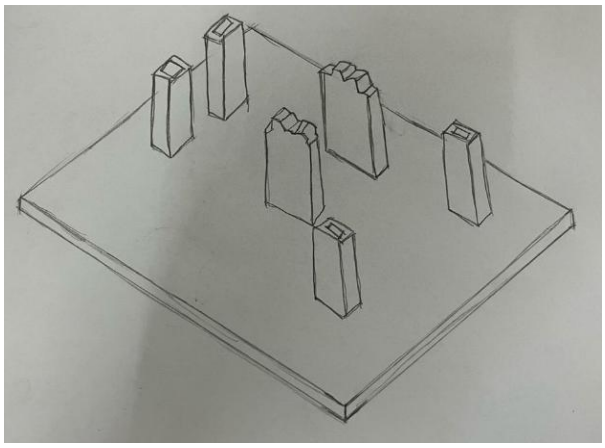

Figure 5: Design 2

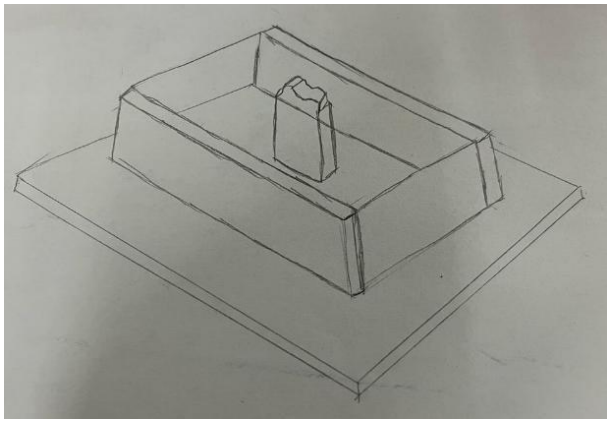

Figure 6: Design 3

2.3 Pugh Method

The Pugh method systematically evaluates designs based on multiple criteria by assigning points according to their importance. Safety is prioritized, especially to prevent harm from sharp edges. Ergonomics, such as including handholds, improves user comfort and usability.

Speed is important for quick and accurate inspections, making faster designs more desirable. Simplicity enhances usability and reduces errors, while lighter designs offer better mobility and ease of transport. Overall, this method provides a comprehensive assessment by scoring designs on these key factors to determine the most efficient fixture.

The Pugh Matrix is a systematic decision-making tool used to compare multiple design options such as Design 1, Design 2, and Design 3 against a set of evaluation criteria. Each design is scored based on how well it meets each criterion, using a standardized scale. The scores are then totaled to identify the most effective design overall. This method helps eliminate bias, ensures consistent evaluation, and highlights strengths and weaknesses across alternatives. By providing a clear, quantitative comparison, the Pugh Matrix supports informed decision-making and encourages design optimization by allowing integration of the best features from various concepts.

The "Legend of Criteria" in the Pugh Matrix plays a crucial role by defining the scoring scale that translates qualitative judgments into quantitative values. By assigning meanings such as -1 for "Not Good," 0 for "Neutral," 1 for "Good," and +1 for "Very Good," the legend ensures consistency and clarity across evaluators, minimizing subjectivity and misinterpretation. This structured scale helps in objectively assessing how each design alternative meets the evaluation criteria, facilitating a transparent and fair comparison. Moreover, it enables teams to communicate evaluations clearly, justify their decisions with evidence, and identify both strengths and weaknesses in design options. Overall, the scoring legend enhances the Pugh Method's value as a rigorous and reliable decision-making tool in engineering and product development processes.

2.4 Fabrication and Testing

Design 2 was chosen for fabricating and testing a fixture at Company X to solve problems regarding the assembly of the seal sub-assy radiator components. The fixture was manufactured to tight quality specifications to meet dimensional accuracy and structural strength. In testing, the new fixture showed strong level of precision and repeatability in maintaining parts held unchanged, ensuring correct positioning of sponge. Important characteristics such as locator support will fix the part in a stationary, accurate position so that there will be no movement during assembly. They eliminate human error, provide even application of the sponge, and enhance the general quality of the product. The fixture also made assembly an easy process and minimized possibilities of manual errors. All in all, testing confirmed the ability of Design 2 to exercise quality control in Company X manufacturing processes, maintaining accuracy of parts.

3.0 RESULTS AND DISCUSSION

3.1 Design Analysis

Three fixture designs of the radiator seal sub-assembly are compared in the Pugh method table shown in table 3.1 based on seven criteria. functionality, cost, quality, safety, weight, and ergonomics as well as total score. Each of the designs scores from -1 to +1 for objective comparison. Every design earned +1 in functionality and safety. Design 1 had the highest scores on cost and weight since it had a simple and lightweight design, however, it had a low-quality score due to inconsistent pressure. The designs 2 and 3 had better scores on quality, of which the 2 balanced moderate cost and weight. Ergonomics favored Designs 1 and 2 while Design 3 was not user friendly because of complexity. Total scores: 4 for (Design 1), 6 for (Design 2), 1 for (Design 3). Design 2 is suggested as the best overall design, which provides the best cost-quality-safety-weight ergonomics ratio.

Table 3.1: Criteria decision

Criteria	Design 1	Design 2	Design 3
Functionality	+1	+1	+1
Cost	+1	1	-1
Quality	-1	+1	+1
Safety	+1	+1	+1
Weight	+1	1	-1
Ergonomics	+1	+1	0
Total	**4**	**6**	**1**

Design 2 was the most beneficial option at the review stage, having the highest scores on several categories. These analyses reveal Design 2 to be the most preferred since it provides the best possible balance between price, quality, safety, weight, and ergonomics. Although Design 1 is a good substitute due to it being simple, it lacks quality assurance as compared to Design 2. Although Design 3 is also characterized by the high standards for quality and safety, it is the least preferred option as it is more expensive and has lower ergonomics. Therefore, for the radiator seal sub-assembly fixture, Design 2 is seen to be the best option.

3.2 Final-Design

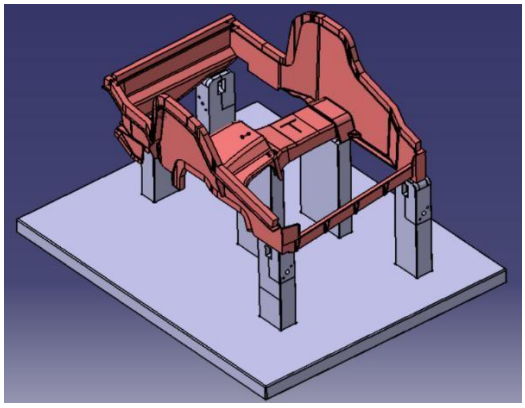

Figure 7: Final Design

Figure 8: New assembly fixture

3.3 Result before and after implementation of assembly fixture

The bar chart displays the monthly defect rate from October 2024 to January 2025 in figure 3.1. The vertical axis represents the defect rate, ranging from 418 to 432, while the horizontal axis lists the months under review. Each bar corresponds to the defect rate for a specific month, with the exact value labelled at the top of each bar.

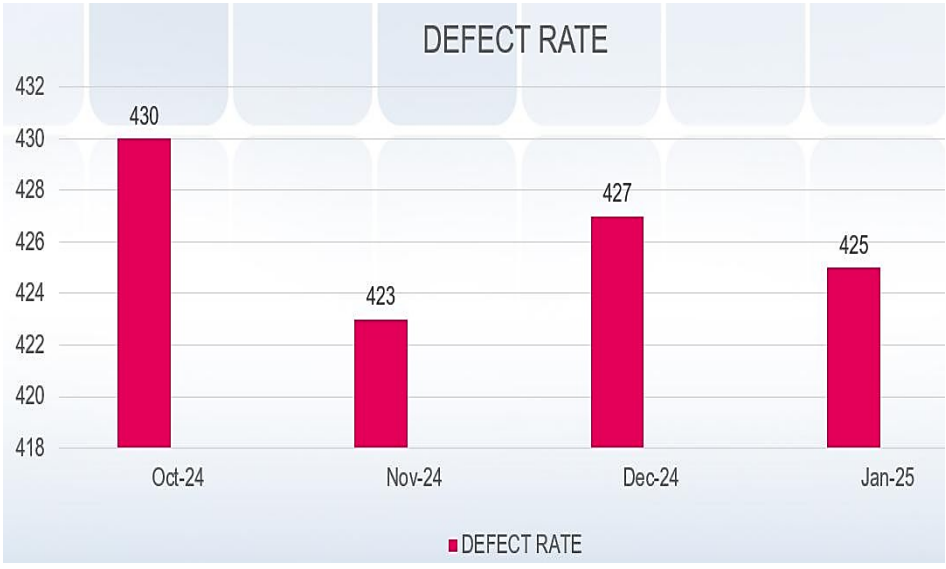

Figure 3.1: Defect rate graph before

In October 2024, the defect rate is at its highest point in this period, reaching 430. There is a noticeable improvement in November 2024, as the defect rate drops to 423, marking the lowest point in the four-month span. However, this improvement is not sustained; in December 2024, the defect rate increases again to 427, indicating a rise in defects compared to the previous month. In January 2025, the defect rate decreases slightly to 425, showing a minor improvement but not returning to the low seen in November.

Overall, the chart reveals a fluctuating trend in defect rates, with an initial significant decrease followed by a partial rebound and a slight reduction at the end. This pattern suggests that while some progress was made in reducing defects after October, maintaining consistent improvement proved challenging, and further action may be needed to achieve a sustained downward trend in defect rates.

The bar chart illustrates the defect rate over three months in figure 3.2, from February to April 2025. The vertical axis represents the defect rate, the horizontal axis displays the months: February, March, and April of 2025.

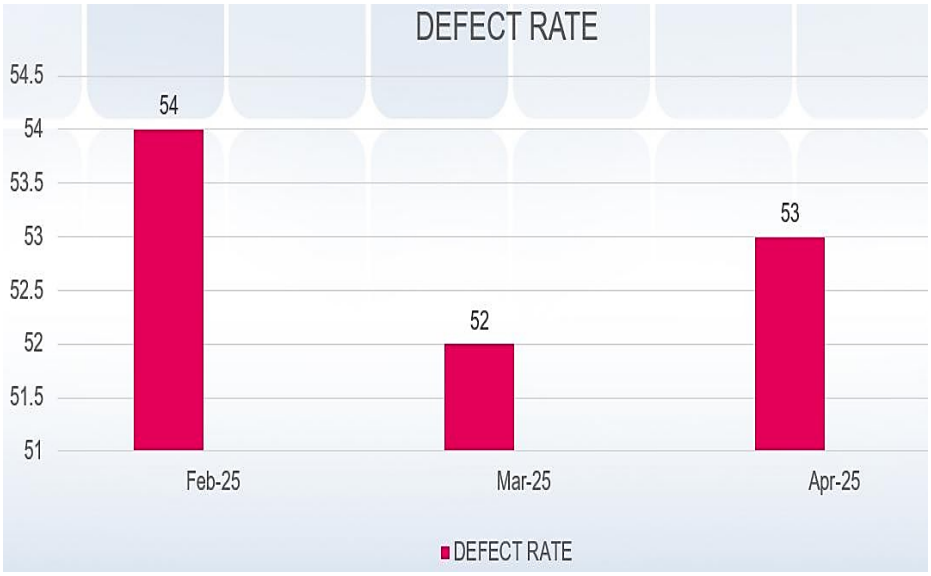

Figure 3.2: Defect rate graph after

In February 2025, the defect rate starts at 54, represented by the first bar. By March 2025, the defect rate decreases to 52, shown by the second, shorter bar. However, in April 2025, the defect rate increases slightly to 53, indicated by the third bar, which is taller than the one for March but still shorter than the one for February.

Overall, the chart indicates a decrease in the defect rate from February to March, followed by a slight increase in April. Despite the increase in April, the defect rate remains lower than the initial rate in February. The data suggests some fluctuation in defect management, with an initial improvement followed by a slight setback.

The number of defective products made between October 2024 and January 2025 was quite high at 423 to 430 per day, before the assembly fixture was introduced. This showed that there were often problems and inconsistencies during manual assembly, leading to more tasks to correct, produce waste, and result in giving low productivity. Yet, once the fixture became

available, the time when defects were seen dropped far down to a range of 52 to 54 for the months of February to April that same year. This major improvement reveals the fixture helps provide more accurate assembly, even sponge application, and good part alignment. For this reason, assembly fixture made products better, decreased mishaps, wasted less material, and boosted how efficiently the operation worked.

4.0 CONCLUSION

The introduction of a custom fixture for seal sub-assy for radiator at company X has increased assembly accuracy, consistency, and improved the entire manufacturing process. The evaluation of three fixture designs according to the Pugh method found that Design 2 offered the most value for cost-effectiveness, quality, safe use, ergonomic considerations, and manageable weight. The reason behind this design was that rigorous testing confirmed it always maintained proper alignment and a uniform level of sponge, ensuring the radiator seals cannot fail.

The manufacturing process improved greatly because of the fixture showing strong results. The number of monthly defects prior to the fixture over 420 showed that there were serious problems with how sponges were assembled by hand, including incorrect placement and lack of straight alignment. During deployment, the fixture cut down the number of defects per month by almost 90%, keeping them below 52 to 54. Since defects have gone down, we have more control over how the parts are assembled, there is less human error, and the process can be repeated more easily. With fewer errors, the quality of goods becomes better and the company saves money by cutting down on material use, repairing unsold items, and reducing the payroll for workers repairing faulty units.

Besides, the fixture has optimized assembly work by automating part placement and enabling less experienced workers to perform their duties with better quality and at a lower energy cost. Ergonomic touches made Design 2 safer for users and led to a workplace that was simple to navigate, supporting more productivity and decreasing the possibility of getting injured there.

As a result, I have learned how big a role detailed fixture play in the modern automotive industry. To fulfill its target of raising market demand, staying ahead of the competition, and providing higher customer satisfaction, company X benefits greatly from fixture due to their rigor, precision, and quality assurance. The achievements of this project show that blending innovation, evaluation, and practical tests in manufacturing improvements can be valuable for later fixture development projects.

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Design and Development of An Optimized Racking System for Bumper Storage Efficiency

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ABSTRACT

This thesis discusses the lack of space to place EV bumpers on the upper bumper rack in the X company production line, which leads to a lack of space to place bumpers before sending to customers. The objective of this project is to design a Work in Progress (WIP) rack that maximizes the placement of bumpers on the rack while improving workflow efficiency. The design process incorporates the use of CATIA V5 software to model and simulate the rack structure. An ergonomic analysis using the REBA method is conducted to ensure that the design is safe and comfortable for workers. Additionally, Lean manufacturing tools such as 5S and Kaizen are applied to enhance workplace organisation and support continuous improvement. The designed racks are tested under actual production conditions to verify their performance. The expected results include improved bumper storage capacity on the upper rack, better ergonomics, enhanced production flow and reduced downtime. This project supports improved quality control, operational efficiency and serves as a benchmark for future manufacturing system optimisation.

Keywords: EV bumper rack, wip rack design, CATIA V5, ergonomic analysis, lean manufacturing

1.0 INTRODUCTION

In today's competitive manufacturing environment, efficient space utilisation and workflow management play a critical role in maintaining high productivity and timely delivery (Smith & Tanaka, 2016). Company X, a company involved in automotive component manufacturing, specifically handles the assembly and storage of bumpers for electric vehicles (EV) under the Perodua brand. One of the main challenges faced on the production floor is the lack of adequate space on the upper bumper rack, which leads to difficulties in storing bumpers temporarily before they are sent to customers (Julian, 2017). This issue causes disruptions in production flow and hinders operational efficiency (Lee et al., 2019).

To address this challenge, the project focuses on the design and development of an optimised Work in Progress (WIP) racking system that can maximize bumper storage capacity while ensuring smooth handling and ergonomics for workers. The study incorporates various engineering and lean methodologies to achieve this objective. The design phase uses CATIA V5 software to model and simulate different rack configurations, ensuring structural feasibility and effective space utilisation (Ahmed & Norazlan, 2020). In addition, the implementation of the Karakuri mechanism, which operates without electricity using gravity and mechanical movements, is explored to enhance the loading and unloading process (Takashi, 2015).

To ensure that the new system is safe and comfortable for operators, ergonomic analysis using the Rapid Entire Body Assessment (REBA) method is applied to evaluate the physical strain on workers during rack interaction (Ghani & Omar, 2018). Furthermore, Lean Manufacturing tools, particularly 5S and Kaizen, are adopted to ensure that the design promotes workplace

organisation, efficiency, and continuous improvement (Yamamoto, 2012; Rahman et al., 2021).

This project not only aims to solve the immediate issue of limited bumper storage but also contributes to long-term productivity improvements. The final design is tested under actual production conditions at Company X to validate its functionality and effectiveness (Chong & Aziz, 2023). Ultimately, the outcomes of this study are expected to support better quality control, operational flow, and serve as a benchmark for future manufacturing system enhancements (Nguyen et al., 2025).

1.1 Background of Study

The rapid growth of electric vehicles (EVs) in the automotive industry has significantly influenced the design and assembly processes within manufacturing plants. Among the critical components in EV production is the bumper, which plays a key role in both aesthetics and safety. In high-volume assembly lines such as those at Company X, where EV bumpers for Perodua models are handled, efficient storage and handling of these large components are vital to maintain smooth production flow and meet delivery timelines.

Work-in-Progress (WIP) racks are used to temporarily store bumpers between assembly processes or before shipment. However, traditional racking systems often face issues such as space limitations, poor ergonomics, and inefficient bumper placement, particularly when dealing with large-sized components like EV bumpers. As the volume of production increases, the lack of an optimised WIP system can result in congestion, longer handling time, and increased risk of damage to parts.

With the demand for more compact and lean production lines, companies are turning to modern design and engineering tools to solve space and efficiency issues. The use of 3D design software such as CATIA V5 enables detailed simulation and modelling of racking systems tailored to specific bumper dimensions and workflow constraints.

To ensure the new system supports worker health and productivity, ergonomic analysis is necessary. The Rapid Entire Body Assessment (REBA) method provides a structured approach to evaluate postural risks during the loading and unloading of bumpers. Furthermore, the integration of Lean Manufacturing practices like 5S and Kaizen ensures that the racking system contributes to overall workplace organisation, cleanliness, and continuous improvement.

By addressing the need for better space utilisation and ergonomic handling, this study aims to develop a racking system that supports both operational efficiency and worker safety in the EV bumper assembly line.

Figure 1: Front Modular Bumper.

1.2 Problem Statement

In the current production process at Company X, a major issue faced on the EV bumper assembly line is the lack of dedicated space for storing completed bumpers before shipping. Due to this limitation, bumpers are temporarily stored in large boxes, which not only occupy excessive floor space but also introduce inefficiencies in the workflow. Each bumper must be manually placed into a box and sealed with tape before being transferred, which is time-consuming and labour-intensive. This process increases handling time, slows down overall production, and poses ergonomic risks to workers who must perform repetitive and physically demanding tasks.

Moreover, the reliance on box storage adds unnecessary material usage and costs, while also reducing the visibility and accessibility of the parts during quality checks or last-minute adjustments. These challenges highlight the need for an optimised Work-in-Progress (WIP) racking system that allows for direct bumper storage without boxing, improves space utilisation, enhances handling efficiency and supports a smoother transition to shipping.

Figure 2: Bumper Installation processes.

Figure 3: The completed bumper assembly had to be placed on top of the box before going into the box.

1.3 Objective

- The main objective is to design and develop a Work-in-Progress (WIP) rack that allows direct storage of EV bumpers and can be efficiently transported into a lorry for delivery without the need for boxing.

2.0 METHODOLOGY

The methodology for this project follows a structured engineering design approach, starting with Problem Identification and Data Collection. This step involves observing the current bumper handling process at Company X, taking measurements of bumper dimensions, available floor space, and recording handling times for boxing and taping. Interviews with workers and supervisors provide additional insights into pain points and improvement opportunities.

Next, the Concept Design is developed using CATIA V5. Various rack designs are created in 3D, taking into account bumper size, weight, lorry dimensions, and available workspace. The

design aims to improve bumper placement efficiency and ensure that the racks can be directly loaded into lorries.

An Ergonomic Analysis using the REBA (Rapid Entire Body Assessment) method is conducted to assess the physical strain involved in operating the rack. This ensures the new system is safe and comfortable for workers, reducing risk of injury from repetitive or awkward movements.

Finally, the results from the testing phase are used in the Final Optimisation step. Feedback from workers and performance data are used to make necessary improvements to the rack, ensuring it is ready for full-scale deployment in the production line. The project flowchart, used in this study as a process flowchart, is depicted in Figure 4 below.

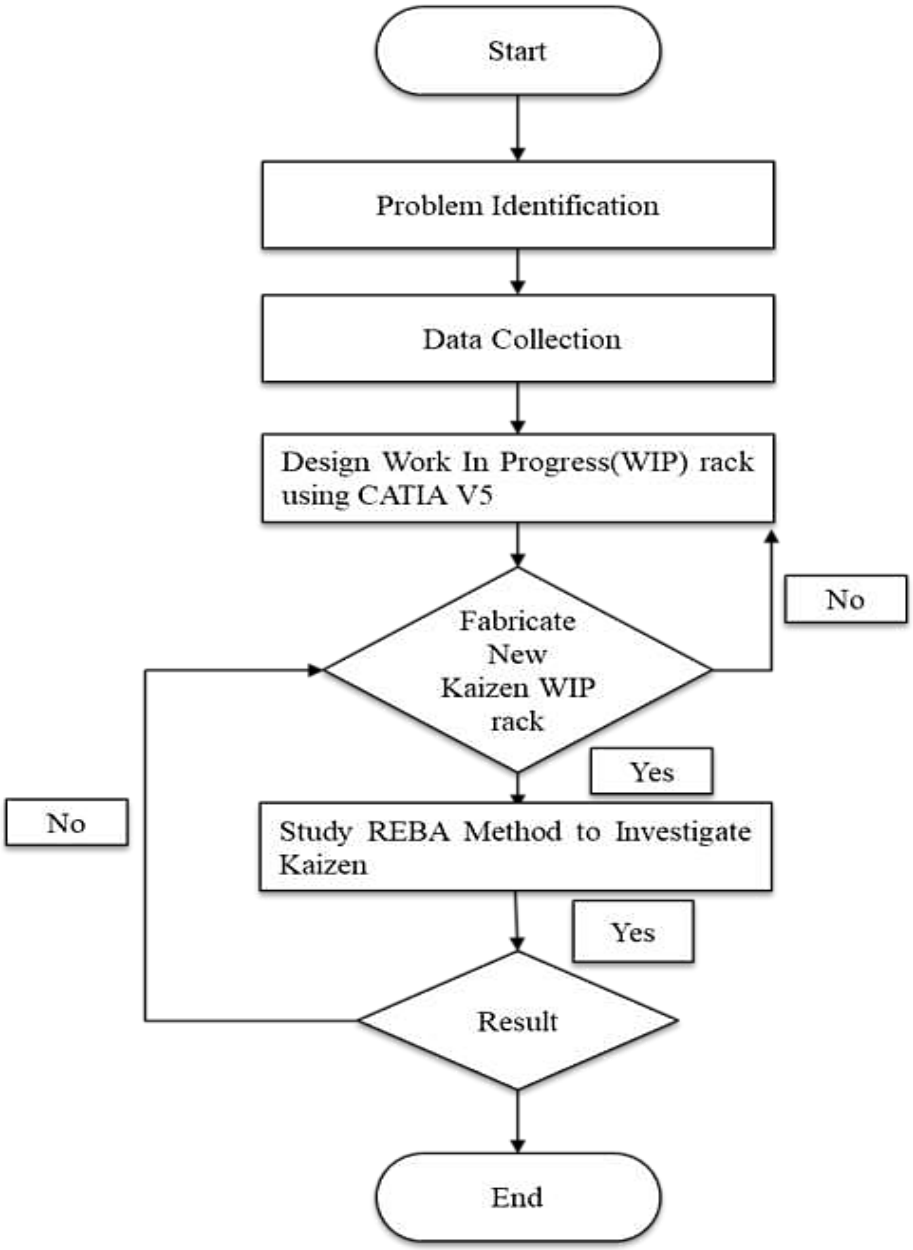


Figure 4: Flow chart for the project.

3.0 RESULTS AND DISCUSSION

The newly designed Work-in-Progress (WIP) rack for electric vehicle (EV) bumpers at Company X demonstrated significant improvements in storage efficiency and operational workflow. The rack, developed using CATIA V5, allowed for easier loading and unloading of bumpers without the need for electrical power. This contributed to a more cost-effective and lean handling process.

3.1 Finding Problem

In the current production setup at Company X, problems were identified in the Work-In-Progress (WIP) and Finished Goods (FG) areas where bumper components are manually handled by operators. This manual process is repeated frequently throughout each shift, covering considerable distances and contributing to increased cycle times, especially during the bumper sub-assembly process. Observations and interviews with operators and line leaders revealed a lack of proper equipment, such as handling tables or racks, which poses ergonomic risks and increases the likelihood of operator fatigue or injury. Additionally, due to rising production demands, the absence of an organised material handling system in the WIP and FG areas has led to inefficiencies and slower production rates. Therefore, the main objective of this project is to design and develop a special racking system that enables efficient movement and storage of bumpers, eliminating the need for manual box handling and supporting faster, safer operations.

Table 1: The rate of economic growth

No	Issue	Corrective Action
1	Inefficient WIP storage for EV bumpers.	Design and implement a space-saving racking system to replace box-based storage.
2	Time-consuming boxing and taping process.	Eliminate packaging steps by using a direct-to-lorry rack system.
3	Delays in production and delivery.	Streamline handling and movement using Karakuri mechanism and lean layout.
4	Poor ergonomic conditions during bumper handling.	Apply ergonomic analysis (REBA) to reduce physical strain and ensure worker safety.
5	Disorganised work area affecting productivity.	Apply Lean 5S and Kaizen principles for continuous workplace improvement.

3.2 Brainstorming

The brainstorming phase was carried out to generate and explore various ideas for designing an effective Work-In-Progress (WIP) rack using the Kaizen concept. This process involved discussions with operators, supervisors, and team members to identify key problems in the current manual handling system, such as inefficiencies, safety risks, and time-consuming processes. Different design possibilities were considered, focusing on how to reduce operator movement, eliminate the need for boxing and taping, and improve material flow. Ideas were sketched out and evaluated based on feasibility, cost, ergonomics, and compatibility with existing production layouts.

3.3 Concept Design

In the concept design phase, two initial rack designs were hand-sketched to explore different layout and mechanism ideas for the Kaizen-based WIP system, focusing on improving bumper storage efficiency, operator accessibility and compatibility with lorry dimensions.

3.3.1 First Design

The first design carries up to 4 bumpers and has four fix caster wheels for convenience. Convenience is a blessing, yet safety is still a concern as the rack tilts and becomes vulnerable to movement when not carrying a full load, posing a potential hazard in case of accidental bumping.

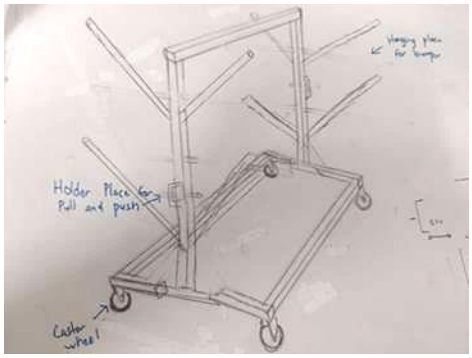


Figure 5: First design

3.3.2 Second Design

The second model is larger in terms of storage, with room for storing multiple bumpers. It features Velcro straps to hold each piece firmly in place while in storage and on the move. In consideration for ease of mobility, the rack also has four caster wheels two swivel and two fixed providing stability as well as ease of movement. Additionally, forklift access holes are also featured in the base, enabling lifting and handling safely and efficiently in the manufacturing area.

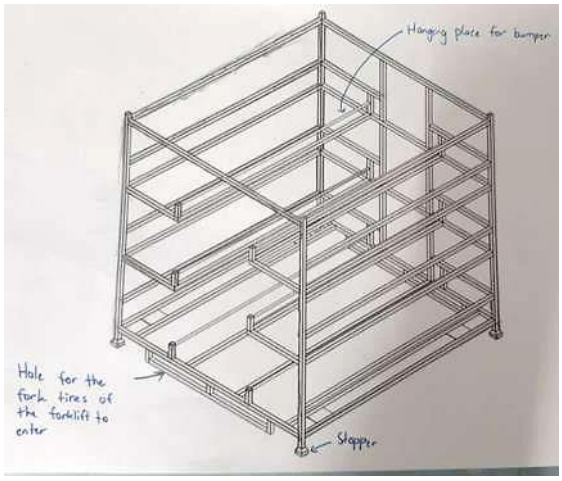


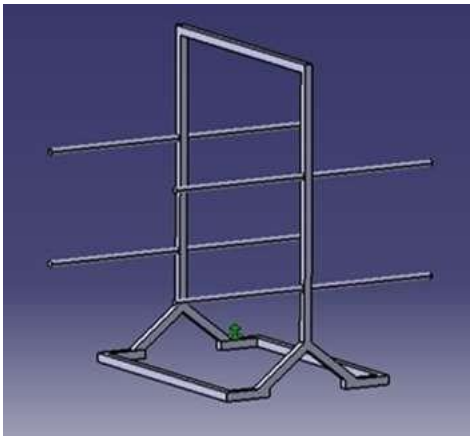
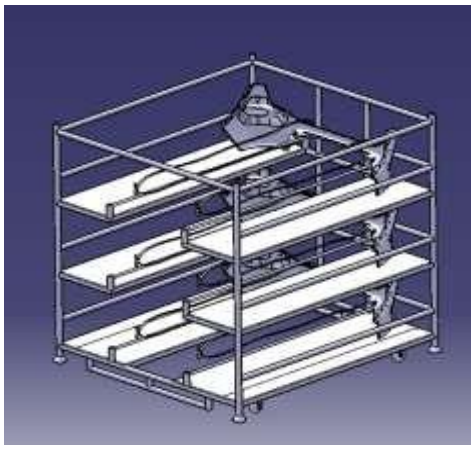
Figure 6: Second design

3.4 Design Selection

Design selection involves choosing the best designs that have been evaluated against specific requirements and criteria using a matrix table. The Kaizen concept will be implemented in the

designated area in a way that does not interfere with existing equipment or processes. This study focuses on minimizing operator waste and boosting productivity in handling the goods. The Kaizen system design is divided into two variations, referred to as Design A and Design B. After the two idea designs are constructed, matrix tables for these separate concept designs are also prepared. The conceptual design and its attributes are given in the matrix table to analyze the design.

Table 2: The Matrix table between design X and Y

Design	**Design A**	**Design B**
		
Material	Mild Steel (MS)–Hollow Square Tubes/Pipes	SS400 (Structural Steel 400)
Length	1900 mm	2300 mm
Width	1700 mm	2100 mm
Total of bumper	4 Bumper can be placed	9 Bumper can be placed
Stability	Stable	Very Stable
Tensile Strength	~400–510 Mpa	~375–460 Mpa
Weight	Slightly heavier than MS due to solid form	Lightweight (hollow design)
Cost	Slightly higher due to plate/bar format	More economical (especially hollow tubes)
Scoring data by operator		
Operator 1	3/10	7/10
Operator 2	3/10	8/10
Operator 3	2/10	9/10
Operator 4	4/10	8/10
Operator 5	2/10	9/10
Total	14/50	41/50

3.5 Result Data Collection

The outcomes of Design A and Design B evaluations are discussed thoroughly in this section. Two forms of analysis were applied to determine the most suitable design to address the issues faced by Company X. The selection process began with a matrix table analysis. This evaluation method helps identify the most effective design solution for the company's operational challenges. A matrix diagram was used as the final stage of the initial assessment. The checklist used in this evaluation was developed by the Centre of Engineering Excellence and is part of a standard procedure for selecting new designs in future projects at Azman Hamzah Plastik Sdn. Bhd. The evaluator in charge will assess various criteria as illustrated in Figure 7.

Statement	Design A	Design B
Ergonomic condition		/
Stability		/
Style Concept		/
Storage number of Bumper		/
Material		/
Costing	/	

Figure 7: Matrix Table Evaluation Sheet

The second method used is Rapid Entire Body Assessment (REBA), which involves asking employees about their behavior and body posture during the work process. The ergonomic analysis conducted using the REBA method showed a lower risk score compared to the previous method. This indicates that the new racking system reduced strain on workers by eliminating repetitive bending and lifting associated with box handling.

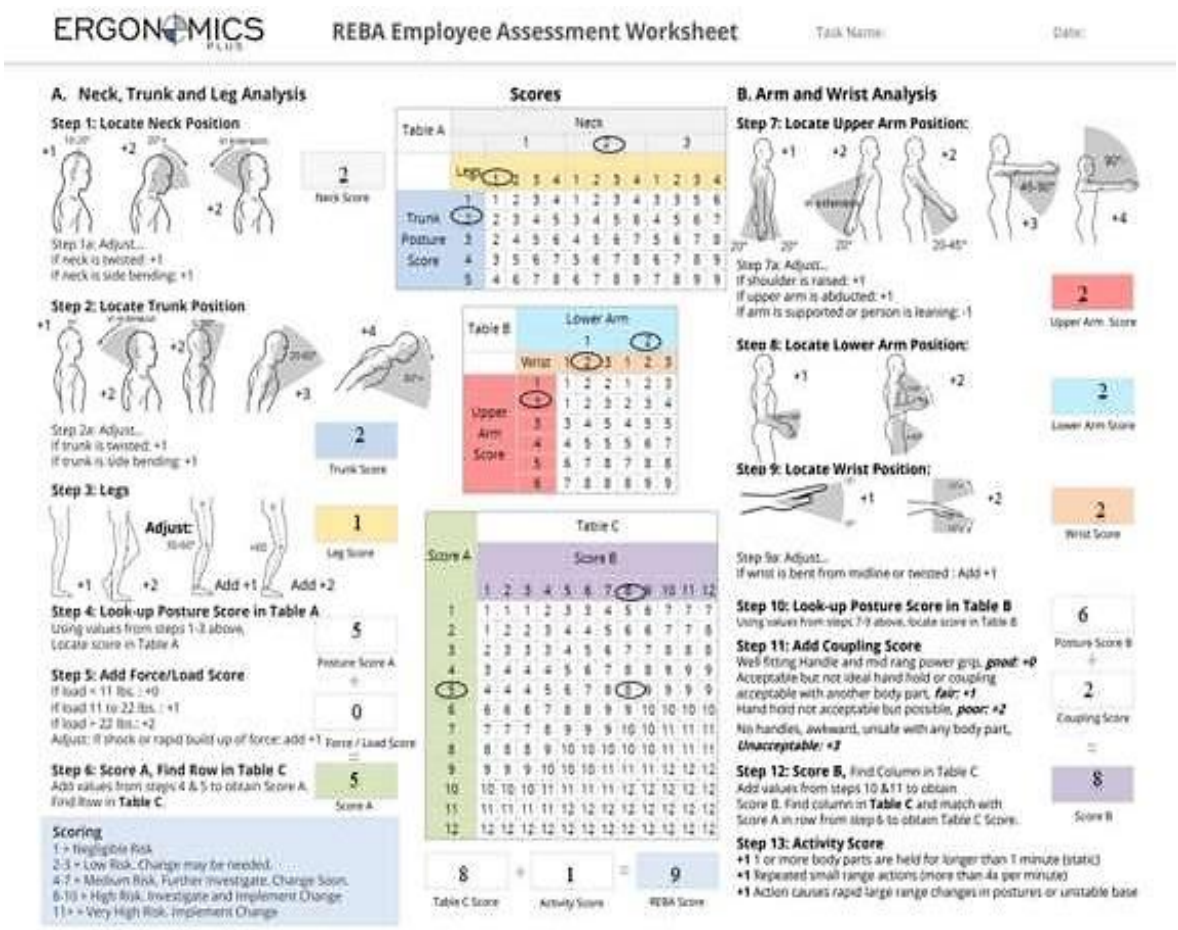


Figure 8: Rapid Entire Body Analysis (REBA) assessment worksheet for design B

Table 3: Calculation REBA

Body Region	Posture Description	Score
Neck	Slightly bent forward while loading bumper	2
Trunk	Bent forward at ~30–60° during placement	2
Legs	Standing with one leg forward	1
Upper Arm	Raised while lifting bumper into rack	2
Lower Arm	Extended during push/pull movement	2
Wrist	Slight twist while gripping bumper	2
Coupling	Fair grip on bumper	1
Load/Force	Handling a moderate load (~5–10 kg)	2

Step Scores:
Group A Score (Trunk, Neck, Legs) = 2 + 2 + 1 = 5
Group B Score (Upper Arm, Lower Arm, Wrist, Coupling) = 2 + 2 + 2 + 1 = 7

Final REBA Score:
Combined A + B + Load/Force = REBA Score: 7

Figure 9: The level of MSD Risk

4.0 CONCLUSION

In conclusion, the design and development of a Work In Progress (WIP) racking system for Company X. successfully addressed the space constraints and inefficiencies previously faced in bumper handling operations. By integrating CATIA V5 for design modelling, the ergonomic assessment using REBA, the new racking system enhances both efficiency and worker safety. Additionally, the application of Lean Manufacturing tools, such as 5S and Kaizen, supports long-term sustainability and continuous improvement. The selected rack design enables direct placement into delivery lorries, eliminating the need for boxing and taping, thus reducing cycle time and improving overall productivity. This project not only solves the immediate storage and handling issues but also serves as a benchmark for future production enhancements in the company.

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Design and Fabrication of a Fixture for Calibrating Power Window Spot Welding Jigs in Automotive Industries

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ABSTRACT
The project focuses on the design and fabrication of a fixture for calibrating power window spot welding jigs in automotive industries, aiming to enhance precision, reduce defects, and improve manufacturing efficiency. The study includes requirement analysis, concept design, fabrication, and testing, demonstrating the superiority of standardized jigs in quality control and production consistency. Key benefits include a 65% reduction in cycle time and an 80% decrease in defect rates, validating the effectiveness of the implemented design.

Keywords: checking fixtures, power window spot welding calibration, automotive manufacturing, welding precision, ergonomic design

1.0 INTRODUCTION.

1.1 Introduction
In modern automotive manufacturing, power window systems are important components that combine functionality, aesthetics, and durability. These systems must meet strict quality and performance standards to ensure smooth and reliable operation throughout the vehicle's lifespan. However, maintaining accuracy and consistency in producing power window assemblies is challenging, especially in large-scale production. Common problems include misaligned parts, poor weld quality, and variation in inspection results. These issues can lead to defective products, increased rework costs, and reduced customer satisfaction (Groover, 2020).

Figure 1: Product

To overcome these challenges, manufacturers use checking fixtures—precision fixtures that help position and align components correctly during the assembly process. Checking fixtures play a key role in improving accuracy, reducing human error, and ensuring repeatable results (Kalpakjian & Schmid, 2018). In power window assembly, checking fixtures are used to check part dimensions and tolerances, while welding jigs hold parts firmly in place during welding

to maintain consistent quality.

Using specialized fixtures for inspection and welding offers several benefits:

1. Higher Accuracy – Ensures components are properly aligned and within required tolerances.
2. Better Efficiency – Speeds up production by simplifying and automating key steps.
3. Consistent Quality – Reduces variation, leading to a more reliable final product.
4. Cost Savings – Decreases rework and material waste, lowering overall production costs (Sharma & Aggarwal, 2015).

This project aims to design and fabricate checking fixtures specifically for inspection and welding in the power window assembly process. The fixtures will be built using durable materials and ergonomic designs to meet the needs of high-precision manufacturing. The study will cover all stages of fixtures development requirement analysis, design, fabrication, testing, and validation.

The successful use of these fixtures is expected to improve manufacturing processes, reduce product defects, and increase productivity. Additionally, the findings from this project could be applied to other manufacturing areas, helping to drive innovation and improve efficiency across the industry.

1.2 Problem Statement

The current method used in the power window spot welding process lacks the precision and consistency needed to effectively detect defects, highlighting the need for a robust and efficient fixture design to standardize checking fixtures, reduce welding defects, and enhance overall quality and efficiency in the power window assembly line.

1.3 Objective

To design and fabricate a checking fixture in power window spot welding to reduce defect and calibration cycle time.

2.0 LITERATURE REVIEW

2.1 Jigs

A jig is a custom-made tool used in manufacturing processes to control the location and motion of another tool. Primarily used in operations such as drilling, reaming, or tapping, a jig serves two main purposes: it holds the workpiece firmly in position and also guides the cutting tool to ensure precision and consistency. This tool significantly reduces human error and increases efficiency, especially in repetitive manufacturing tasks. Drill jigs, for example, are commonly used to ensure that holes are drilled in the correct position with consistent depth and angle. Jigs are typically lighter in construction compared to fixtures because they are designed for portability and ease of use. Their application is especially valuable in batch production or assembly line processes where maintaining accuracy across multiple components is critical (Joshi, 2010; HMT, 2000).

2.2 Fixtures

A fixture is a device used in manufacturing to securely hold, support, and locate a workpiece during machining or assembly operations, but unlike jigs, it does not guide the cutting tool. Fixtures are crucial in processes such as milling, turning, and grinding, where the tool path is

controlled by the machine, and the stability of the workpiece is essential. By maintaining the correct orientation and positioning of the workpiece, fixtures help improve machining accuracy, surface finish, and operator safety. They are generally heavier and more robust than jigs to withstand the cutting forces involved in machining. Fixtures can be custom designed for specific parts or made adjustable to handle a variety of components, making them indispensable in both mass production and specialized manufacturing (Kalpakjian & Schmid, 2014; Rao, 2013).

2.3 Checking Fixtures

A checking fixture is a precision tool used in the manufacturing and quality control process to inspect the dimensional accuracy, shape, and fit of a manufactured part. Unlike machining fixtures that assist in the production of parts, checking fixtures are used post-production to verify that parts conform to design specifications and tolerances. These fixtures are typically designed based on the CAD model of a part and include features such as datums, gauges, pins, and clamps to hold and inspect critical dimensions. Checking fixtures are widely used in industries like automotive and aerospace, where maintaining tight tolerances is crucial for assembly and performance. They enable fast, repeatable, and non-destructive inspection processes, reducing reliance on CMM (Coordinate Measuring Machine) inspections and improving overall production efficiency (Rao, 2013; Kalpakjian & Schmid, 2014). Their use is especially important in high-volume production, where consistent part quality must be ensured without slowing down the workflow.

2.4 Precision and Tolerances

Maintaining tight tolerance is critical in jig manufacturing to ensure accuracy and repeatability. Key factors include selecting stable materials like hardened steel or aluminum, using advanced CNC and laser machinery for high precision, implementing rigorous quality control with tools like CMMs, and applying surface finishing techniques to enhance dimensional accuracy and reduce wear.

2.5 Ergonomics in Fixtures Design

Ergonomics in fixtures design enhances operator comfort, safety, and efficiency, especially in high-volume manufacturing. Key factors include reducing weight, incorporating ergonomic handles, and simplifying alignment. Modular fixtures further improve adaptability and reduce tool changeover time. Ergonomic features such as easy-to-use clamps, intuitive interfaces, and safety mechanisms reduce strain, errors, and workplace injuries. Overall, ergonomic fixtures boost productivity, lower defect rates, and support lean manufacturing by making tools user-friendly and adaptable.

2.6 Concept Design

Concept design is a foundational phase in product development where ideas are generated and evaluated to meet defined requirements. It emphasizes creativity, functionality, and feasibility, using tools like the Pugh Matrix to compare options. The outcome is a refined concept ready for detailed design and development.

2.7 Pugh Metrix

The Pugh Matrix is a decision-making tool developed by Stuart Pugh to compare alternatives against a baseline using a set of defined criteria. It simplifies complex decisions, promotes team consensus, and reduces bias. While useful, its basic scoring system may oversimplify evaluations, prompting the use of hybrid methods like AHP for greater accuracy. Widely

applied in engineering, product design, and lean manufacturing, the Pugh Matrix remains a valuable tool for structured, objective selection processes.

3.0 METHODOLOGY

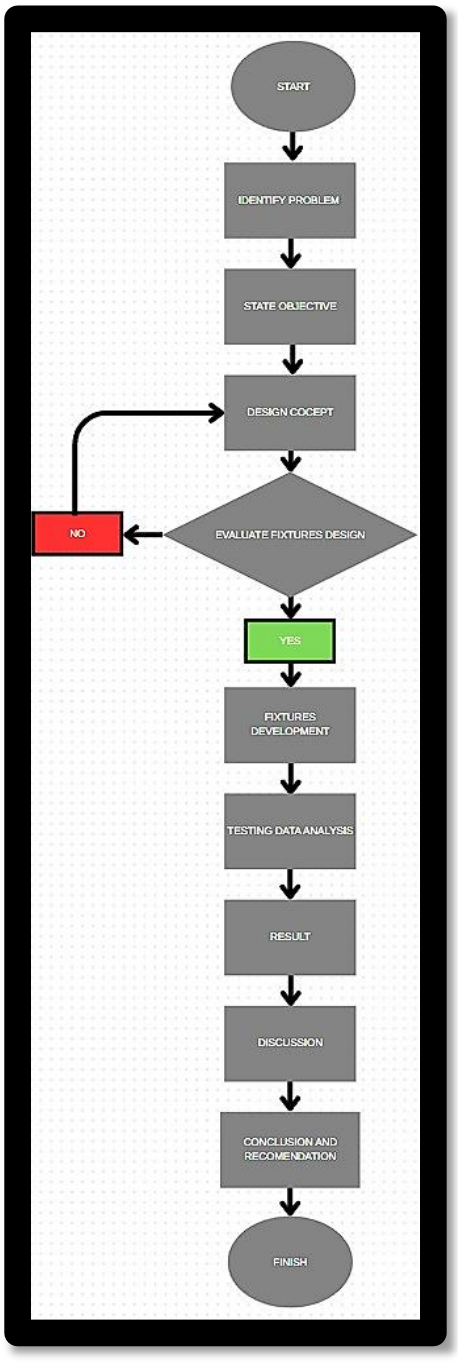

Figure 2: Flow Chart

3.1 Identify Problem

Problems were identified through direct observation and Gemba walks at the workstation. It was observed that operators were manually handling the jigs, which often resulted in frequent misalignments and inconsistencies during the welding process. These issues contributed to an increase in product defects and extended the overall production time.

3.2 Objectives

The objective of this project is to design and fabricate checking fixtures for spot welding jigs that ensure proper alignment, reduce human error, improve welding consistency, and shorten setup time. Additionally, the checking fixtures must be ergonomic and compatible with the existing welding equipment to support seamless integration into the current production process.

3.3 Design Concept

The design process begins with initial hand-drawn sketches to visualize the basic structure and function of the checking fixtures. These sketches help generate ideas for the overall layout, component placement, and clamping mechanisms, serving as the foundation for further development. Once the sketches are refined, the design is transferred into 2D technical drawings to define critical dimensions, tolerances, and key alignment features, which guide the initial assessment of fit and functionality. The finalized design is then modeled in CATIA V5, a computer-aided design (CAD) software, to create accurate 3D representations of the checking fixtures. These models enable detailed analysis of component interactions, operator accessibility, part alignment, and structural integrity. valuate Fixtures Design

To determine the most effective fixture design, three different concept designs are compared using the Pugh Selection Method. Each concept is evaluated based on key criteria such as cost, ease of manufacturing, weight, ergonomics, and safety in relation to the existing spot-welding process. The Pugh matrix provides a systematic approach to identify the strengths and weaknesses of each design, enabling an objective comparison that supports data-driven decision-making. Upon completing the evaluation, the concept with the highest total score and the best balance of performance and practicality is selected for further development. This structured decision-making process ensures that the final jig design is not only technically sound but also aligned with the production goals.

3.4 Fi tures Fabricate

Once approved, the checking fixture is fabricated using appropriate materials and processes, such as CNC machining. Dimensional checks are performed on all components to ensure accuracy and conformity with the CAD model, guaranteeing that the final product meets design specifications and functions as intended.

3.5 Testing and Data Analysis

The checking fixture is tested under actual production conditions to assess its real-world performance. During this phase, data is collected on key parameters such as welding accuracy, cycle time, setup time, and defect rates. Evaluation tools such as Statistical Process Control (SPC), time studies, and defect analysis are employed to thoroughly analyse the fixture's effectiveness and identify any areas for improvement.

3. Discussion

The test results are analyzed and discussed in relation to the original problems and objectives to determine the effectiveness of the checking fixture. Any deviations from the expected outcomes are carefully examined, and possible reasons for these discrepancies are identified. Additionally, opportunities for further improvements or design enhancements are explored to optimize the fixture's performance and better align it with production needs.

4.0 RESULTS AND DISCUSSION

In this section, look over the findings from the issue that was discovered as well as the final design chosen using the Pugh method and Weight decision method. Several potential solutions were considered after a thorough analysis and evaluation of the problem. To objectively assess the proposed designs based on predefined criteria, the Pugh method, a structured approach for concept selection, was used. Each design was assessed using the established criteria, which considered factors such as cost, ease of manufacturing, weight, ergonomic and safety. The design that demonstrated the highest performance and met the specified criteria was chosen as the final design after a rigorous evaluation process. The Pugh method was used to ensure a systematic and data-driven approach to decision-making, which resulted in the identification of the best possible approach to solve the problem.

4.1 Method Before Improvement

Figure 3: Spot Weld jig

In the initial phase of this project, the calibration of spot-welding jigs for power window assemblies was performed manually. This method involved the use of hand tools, visual alignment, and operator judgment to achieve the required positioning accuracy. While effective to a certain extent, the manual process was time-consuming, operator-dependent, and prone to inconsistencies. The variability in cycle times and defect rates highlighted the limitations of this approach, prompting the development and deployment of a standardized checking fixtures system to improve calibration efficiency and product quality.

4.2 Design Decision

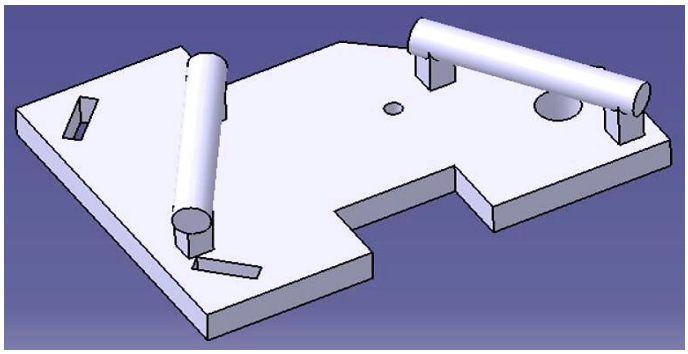

Figure 4: Design 1

Design 1 was selected as the optimal fixtures design based on the Pugh Matrix evaluation, achieving the highest overall weighted score of **4.65** out of **5**. This design demonstrates strong performance across all key criteria, making it a well-rounded and practical choice. In terms of cost, **Design 1** offers a favorable balance between simplicity and functionality, keeping production expenses reasonable. It excels in ease of manufacturing due to its straightforward geometry, minimal complex features, and ease of assembly, making it highly compatible with standard machining and fabrication processes. The design is also relatively lightweight, thanks to its open structure and efficient use of material, which contributes to easier handling on the shop floor. Ergonomically, it provides well-placed supports and handles, offering user comfort and reducing strain during operation. Safety is another strong point, as the design incorporates secure positioning elements that minimize the risk of part movement or operator injury. Overall, Design 1 stands out as a cost-effective, easy-to-manufacture, ergonomic, and safe fixtures solution that meets both operational and user-focused needs effectively.

4.3 Fabricate

Figure 5: Checking fixture (top view)

Figure 6: Checking Fixtures (bottom view)

Fabrication workflow of the checking fixture based on CAD design output and Pugh Metrix. The process includes material preparation, precision machining of datum surfaces, and integration of locating elements to meet dimensional inspection standards.

4.4 Data Collection

The data collection of **cycle time** and **defect data** is shown before and after implementing the fixtures and how the data set changes after the checking fixtures are designed.

4.4.1 Cycle Time Before and After Implementation.

Cycle time refers to the duration required to complete the calibration of a spot weld jig. Time measurements were recorded for both the manual calibration method and the new checking fixtures process.

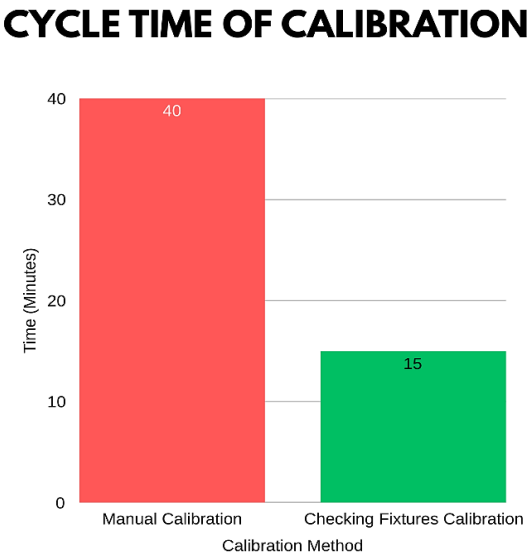

Figure 7: Comparison of cycle time before and after implementing checking fixtures

Manual Calibration: The cycle time ranged from 45 minutes per jig, depending on the operator's experience and the complexity of the adjustments required. This process was labour-intensive, involving multiple checks and realignments using gauges and manual measurements.

Checking fixtures: After implementation, the average cycle time was reduced to 15 minutes per jig. The checking fixtures enabled faster setup by guiding components into predefined, repeatable positions, eliminating the need for repeated manual adjustments. The cycle time data illustrates a time efficiency gain of approximately 65%, contributing to reduced labour hours, increased throughput, and more consistent production scheduling.

4.4.2 Defect Data Before and After Implementation

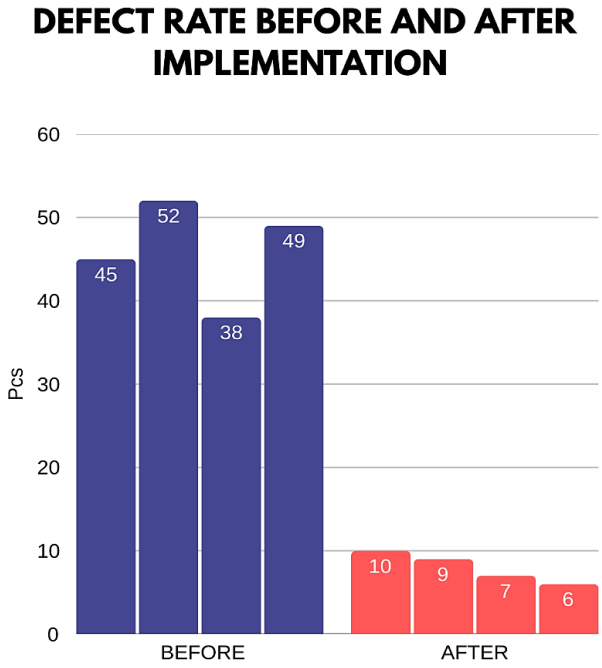

Figure 8: comparison graph defect data before and after implementation

Defect data was collected over a four-week period to compare the quality performance before and after the implementation of a checking fixture for spot weld jig calibration. Each week, 7,200 units were produced, amounting to a total of 28,800 units per condition (manual vs. Checking fixtures).

Before the checking fixtures were introduced, the defect count per week ranged from 38 to 52, with an average of 46 defects per 7,200 units, yielding an average defect rate of approximately **0.639%**. Common defects included weld misalignment, insufficient penetration, and inconsistent weld spacing issues typically resulting from manual calibration variability.

Following the implementation of the checking fixtures, defect counts dropped significantly, ranging from 6 to 10 per week. The average defect rate during this period was approximately **0.111%**, indicating a reduction in defects of over **80%**. This improvement demonstrates the positive impact of standardized calibration on weld quality and repeatability.

5.0 CONCLUSION

The implementation of the checking fixtures for power window assembly calibration significantly improved manufacturing processes. It reduced cycle times, minimized defects, and enhanced product quality and consistency. The ergonomic design contributed to operator efficiency and safety. These advancements demonstrate the value of precision tooling in addressing production challenges, setting a precedent for further applications in other manufacturing domains. Future work could explore modular designs for broader usability and cost-effectiveness.

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Design and Fabrication of a Nut Knocking Jigs for Detecting Nut Detachment in Spot Weld Machine

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ABSTRACT

This study focuses on the design and fabrication of an automated nut knocking jig to detect nut detachment in spot welding machines, specifically for the Member Front Side Inner RR LH/RH. The current manual inspection method is time-consuming, prone to human error, and leads to operational delays, inconsistent product quality, and high rejection rates. To overcome these challenges, the root causes of nut detachment were identified using structured problem-solving tools such as the Fishbone Diagram and the 5 Why method, which helped trace issues back to ineffective manual inspection techniques and lack of real-time validation. Based on these findings, three conceptual jig designs were developed using CATIA software for 3D modeling and technical drawing generation. The Pugh method was then applied to compare designs based on criteria such as accuracy, ease of use, cost, and reliability, leading to the selection of the most effective jig concept. The selected design was then fabricated using standard manufacturing techniques, including precision cutting, welding, drilling, and assembly to ensure durability and performance. The final jig integrates automation to eliminate manual intervention and provides precise, real-time detection of loose or detached nuts during the spot-welding process. Testing and prototyping demonstrated a 31% improvement in overall inspection efficiency, significant cycle time reduction, and enhanced product quality. This project offers a practical and cost-effective solution to improve quality control in spot welding operations, while also providing valuable insights into optimizing inspection systems, reducing downtime, and increasing manufacturing productivity.

Keywords: spot welding, nut knocking jig design, CATIA V5, pugh method, detachment on part.

1. INTRODUCTION

1.1

The automotive industry demands strict standards of quality, efficiency, and safety, particularly in critical processes such as spot welding. Spot welding is a resistance welding process in which contacting metal surfaces are joined by the heat obtained from resistance to electric current. It is widely used in the automotive sector due to its speed, reliability, and suitability for joining sheet metals. Components such as the Member Front are essential for vehicle structure and passenger safety. At Company B, the current manual inspection method for checking welded nuts has led to alignment issues, reduced accuracy, and inconsistent quality during the assembly process. This project was initiated based on direct observations at the Gemba (workplace), where a Company B Technician-Assistant identified inefficiencies in the existing nut knocking process. The current method relies heavily on manpower, resulting in frequent misalignments and potential defects in welded parts. The project targets improvements for the Member Front, which is assembled using nut welding. These defects are critical and can lead to customer complaints if not addressed properly. By enhancing the nut knocking jig design, this project aims to improve alignment accuracy, reduce human error, and ensure higher consistency in spot welding operations for the Brand X model.

1.2 Problem Statement

Nut detachment during assembly is a recurring issue in automotive manufacturing, often resulting in production delays, increased costs, and potential safety concerns.

In the Production Line at Company B, nuts are spot-welded to components such as the Member Front, making secure attachment crucial for maintaining product quality and operational efficiency. The lack of a proper jig significantly reduces process accuracy and consistency, leading to higher defect rates. Jigs play a vital role in assembly by ensuring precise alignment and stability during welding operations. Without them, the risk of misalignment and undetected defects increases, directly impacting productivity, product reliability, and overall customer satisfaction. A specialized nut knocking jig is essential for detecting loose or detached nuts before final assembly, especially for high-precision parts like the Member Front. This helps ensure high- quality welds, reduce rejection rates, and prevent production disruptions. In 2023–2024, these parts recorded a high defect rate of 30%–40%, leading to frequent customer complaints and internal quality check failures. Given the critical role these components play in vehicle structure and safety, addressing the root causes of these defects through improved jig design is necessary to restore product quality, enhance customer trust, and protect the company's reputation.

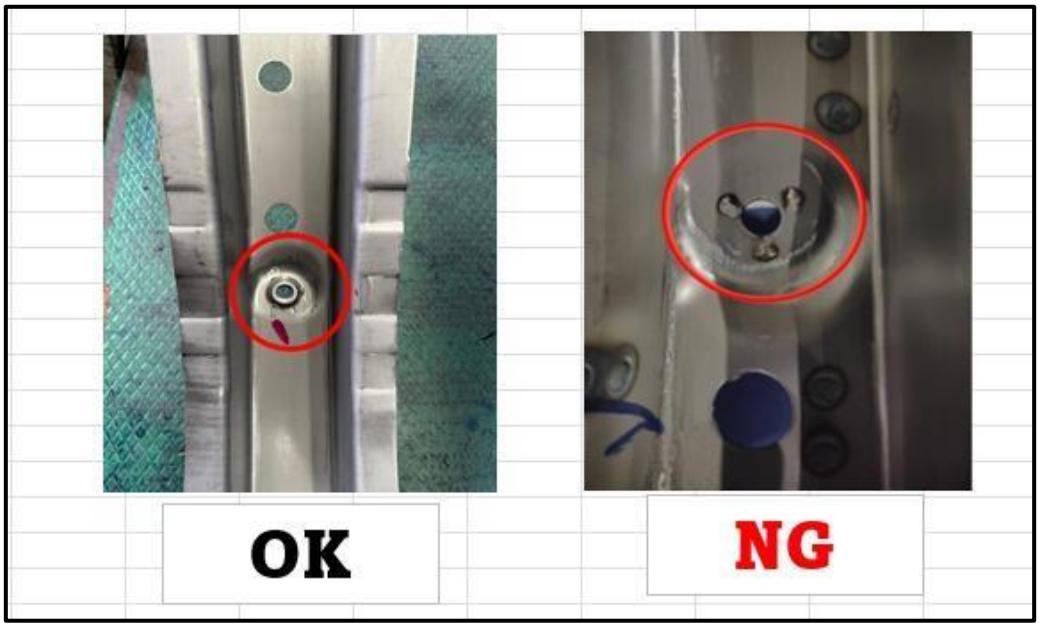

Figure 1: Comparison between OK and NG part.

1.3 Objective

i. To design a nut knocking jig to prevents loose or detached nuts in spot welding machine.
ii. To evaluate the performance of nut knocking jig during implementation in spot weld process.

1.4 Literature Review

1.4.1 Jigs and Fixture

Jigs and fixtures are essential tools in machining and manufacturing processes, helping to produce accurate, consistent, and interchangeable parts. Widely used in workshops and production environments, they improve efficiency, precision, and repeatability. A jig holds a workpiece in place and guides tools like drills, cutters, or welders to ensure consistent operation, making it particularly useful in tasks such as drilling, spot welding, assembly, and machining. For example, in spot welding, a jig maintains the correct alignment of metal sheets,

allowing for uniform and precise welds. By minimizing human error and reducing dependence on skilled labor, jigs increase production speed and enhance product quality, especially important in mass production, where uniformity is key. They also help cut down on machine setup time and enable even less experienced operators to achieve high precision. When designing jigs and fixtures, important factors include cost-effectiveness, simplicity, durability, accuracy, lightweight construction, and ease of use. Reliability over time is crucial, and added features such as portability, easy maintenance, effective fluid delivery, and operator safety measures further improve their performance and value in manufacturing settings. (Radhwan)

1.4.2 Spot-Welding Machine

A spot-welding machine is a device used to join two or more metal sheets together by applying pressure and heat to a small area. It operates by clamping the metal pieces between two copper electrodes and passing a high electric current through them. The resistance at the contact point generates intense heat, which melts the metal and forms a strong weld upon cooling. Spot welding is especially effective for thin sheet metals and does not require filler materials, making the process efficient, clean, and cost-effective. These machines are widely used in industries such as automotive manufacturing, where speed, accuracy, and reliability are crucial for high-volume production. There are various types of spot-welding machines available, including handheld, bench, pedestal, and robotic models, each tailored to specific applications. In the context of this project, which focuses on improving the nut welding process for the Member Front assembly, the spot-welding machine plays a vital role. By integrating a specially designed nut knocking jig, the alignment of parts during spot welding can be significantly improved, reducing human error, enhancing welding accuracy, and ensuring higher product quality and consistency in mass production environments. (Bogaerts)

1.4.3 Poka Yoke Method

The concept of Poka-Yoke, introduced by Shigeo Shingo as part of the Toyota Production System, refers to mistake-proofing methods designed to prevent human errors in manufacturing processes. It plays a critical role in enhancing product quality and efficiency, especially in repetitive tasks on automotive assembly lines such as those at IQM Bukit Beruntung. Poka-Yoke mechanisms, whether contact type, fixed-value type, or motion-step type, help detect or prevent defects by guiding the operator or the process to perform correctly. In the context of this project, which focuses on designing a nut knocking jig to improve efficiency and product quality, the principles of Poka-Yoke are directly applied to minimize errors during the nut removal process. Problems such as misaligned or incompletely removed nuts, and damaged threads, are addressed through jig features like fixed positioning guides for proper alignment, stopper mechanisms to ensure full removal, and ergonomic enhancements to reduce fatigue. By integrating these features, the jig ensures standardized operation, reduces reliance on operator skill, and contributes to consistent quality. Studies in similar manufacturing environments support that Poka-Yoke-based jigs significantly reduce defects, improve first-pass yield, and enhance line productivity. Therefore, the application of Poka-Yoke in this project serves as a practical solution to eliminate common errors, reduce cycle time, and support IQM's continuous improvement objectives in line with lean manufacturing principles. (Al Ayyubi)

1.4.4 Pugh Method

The Pugh Method, also known as the decision-matrix method or Pugh Concept Selection, is a systematic technique used for comparing multiple design alternatives against a set of weighted criteria to identify the most effective solution. Developed by Stuart Pugh, this method is widely

applied in engineering and manufacturing decision-making processes, particularly during the early design stages of product or tool development. In this project, which focuses on designing a nut knocking jig to improve the efficiency and product quality at IQM's assembly line, the Pugh Method was used to evaluate different jig concepts based on critical factors such as cost, ease of use, safety, durability, error-proofing capability (Poka-Yoke), and compatibility with existing workstations. Each concept was compared against a baseline design and rated using a structured matrix that allowed for objective selection of the most suitable design. This method helped ensure that the final jig design was not chosen based on intuition alone but through a data-driven approach that balanced functionality, user ergonomics, and production needs. By using the Pugh Method, the project minimized design risks and aligned the jig development with IQM's lean manufacturing goals, contributing to better line balance, reduced defects, and improved cycle time in the nut removal process.

2.0 METHODOLOGY

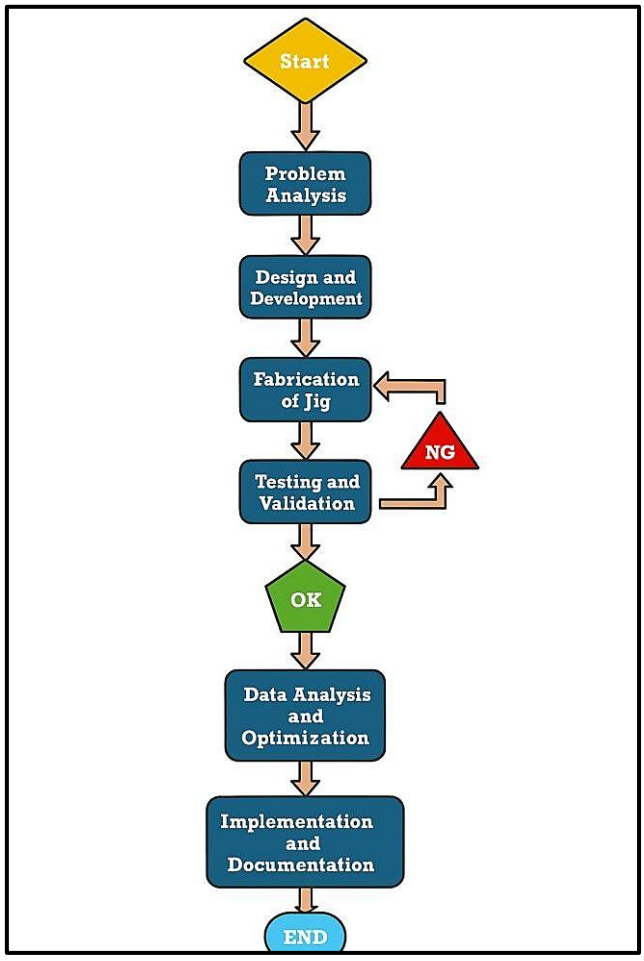

Figure 2: Flow Chart of making Nut Knocking Jig

Jigs are vital tools in high-volume manufacturing, especially in the Spot Weld Stationary (SWS Line) of the Production Line, where they improve precision, repeatability, and overall efficiency. Jig designs have evolved from simple alignment tools to advanced modular and automated systems, supported by CAD and CAM technologies that help reduce human error, shorten production time, and enhance process reliability. Sandwich jigs are ideal for lightweight parts, providing greater strength, stability, and quicker assembly. This chapter also

highlights the importance of lean manufacturing principles such as waste reduction, Poka-Yoke (error-proofing), and Kaizen (continuous improvement) to streamline workflows and boost productivity. Design tools like CATIA V5 are essential in this process, offering geometric analysis and manufacturing simulations to refine and validate jig designs. Evaluation methods, including the Pugh Matrix, cycle time analysis, and other performance metrics, are used to assess and compare design alternatives based on criteria like cost, weight, and safety. By combining advanced design tools with lean strategies, the chapter presents a complete approach to developing customized jigs that enhance both productivity and product quality in the SWS Line.

2.1 Identify Problem

The fishbone diagram, also known as the Ishikawa diagram, is a problem-solving tool developed by Dr. Kaoru Ishikawa in the 1960s that helps identify and analyze the root causes of problems by organizing them into six categories: People, Methods, Machines, Materials, Measurements, and Environment. This visual and structured approach aids in pinpointing key factors contributing to process inefficiencies. In this research, the fishbone diagram was used to examine problems in the current spot-welding process, particularly with the manual hand jig used to hold parts. The existing jig lacks both flexibility and stability, leading to part misalignment and poor weld quality. These issues were highlighted by a supervisor who saw the need for a better-designed nut-knocking jig to ensure more consistent and accurate welding results. This project aims to design and fabricate an improved manual nut-knocking jig to overcome these limitations. By applying the fishbone diagram to identify contributing factors, the study establishes a clear improvement plan focused on enhancing precision, reducing welding defects, and increasing overall efficiency in the spot-welding operation. (Cervone)

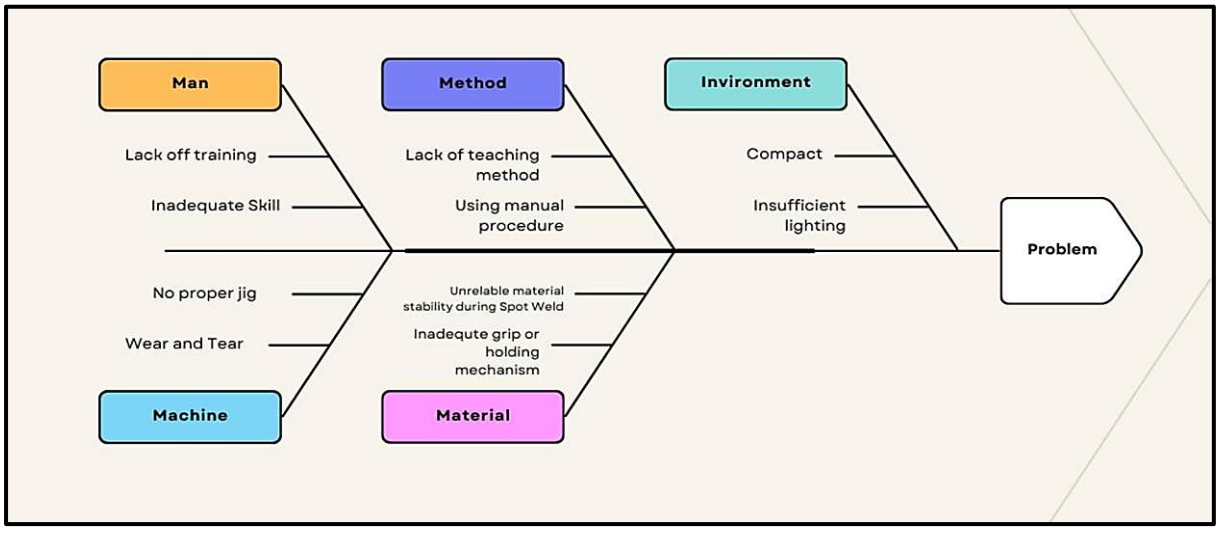

Figure 3: Ishikawa Diagram to identify the problems.

Figure 3 highlights the key factors contributing to the identified problem, grouped into five categories: Manpower, Method, Environment, Machine, and Material. Under “Manpower,” the main issue is the lack of proper training and technical skills among operators, leading to improper handling and lower productivity. The “Method” category points to the absence of structured maintenance routines and well-defined standard operating procedures (SOPs), which creates process inefficiencies. In the “Environment” section, poor lighting and limited workspace are major obstacles that disrupt smooth operations. The “Machine” category identifies problems such as ineffective jig design, lack of automation, and worn-out equipment,

all of which compromise machine performance and reliability. Finally, the "Material" category includes concerns like substandard jig construction, unstable part positioning during welding, and weak clamping mechanisms. Addressing these issues systematically can improve the inspection process, enhance product quality, boost efficiency, and reduce defect rates.

2.2 Concept Generation (Sketching)

Design 1, shown in Figure 4, is an early concept for a manual nut-knocking jig that emphasizes simplicity and ease of use. It operates by pulling a vertical lever to deliver a mechanical knock, allowing workers to check for loose nuts after spot welding. Fixed to the workstation table, the jig offers stability and minimizes repositioning, making it suitable for repetitive assembly tasks. Its structure includes a sturdy support column, a horizontal guide bar, and a striking mechanism positioned above the part-holding area. The lever is manually lifted to apply the knocking force, providing direct operator control without the need for complex automation. However, this design presents safety concerns, as workers must lift the lever with one hand while aligning the part with the other, increasing the risk of hand injuries if the rod slips or falls due to fatigue or mishandling. Additionally, the absence of an ergonomic grip or safety shield may cause discomfort and inconsistent knock over time. Although the design is simple and cost-effective, future improvements should focus on enhancing safety and ergonomics such as adding a spring-loaded handle, protective guard, or two-handed operation without affecting inspection accuracy

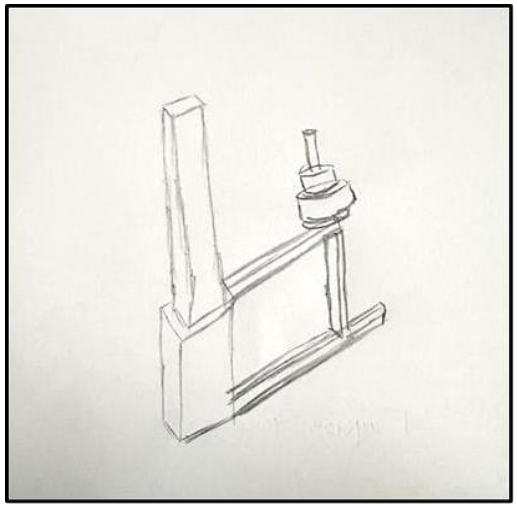

Figure 4 Concept Design 1

Design 2, shown in Figure 5, offers several key improvements over the initial concept by enhancing both ergonomics and operator safety. The main upgrade is the repositioning of the lever to the top of the load, allowing workers to lift it more comfortably with less physical effort, which reduces strain on the hand and wrist during repetitive tasks. This not only improves usability and reduces fatigue but also lowers the risk of injury. Unlike Design 1, where operators had to lift a vertical rod in a potentially unsafe way, Design 2 provides a more secure and controlled grip, minimizing the chance of the lever slipping or falling. The elevated lever position keeps the operator's hands away from moving parts, further improving safety. Additionally, the ergonomic design allows for smoother, more consistent application of force, leading to better inspection accuracy and fewer defective parts. Overall, by reducing physical effort and improving safety, Design 2 helps maintain high productivity and quality during the spot-welding inspection process.

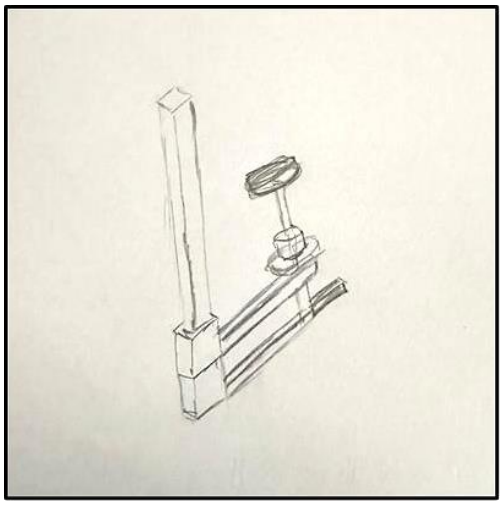

Figure 5: Concept Design 2

Design 3, shown in Figure 29, builds on the foundation of Design 1 by adding key features that improve flexibility and user convenience. Unlike the fixed-base setup of the earlier design, Design 3 includes a mobile structure that allows the nut-knocking jig to be easily moved between different workstations, offering greater versatility on the assembly line. A major enhancement is the addition of a pulley lever mechanism positioned at the back right side of the jig, which reduces the physical effort needed from operators and enables smoother, more controlled knocking actions. This not only makes inspections easier but also improves the accuracy in detecting loose or detached nuts during the spot-welding process. By combining mobility with ergonomic upgrades, Design 3 improves workflow flexibility, reduces operator fatigue, and enhances inspection precision, resulting in a more efficient and user-friendly solution for maintaining quality in the assembly process.

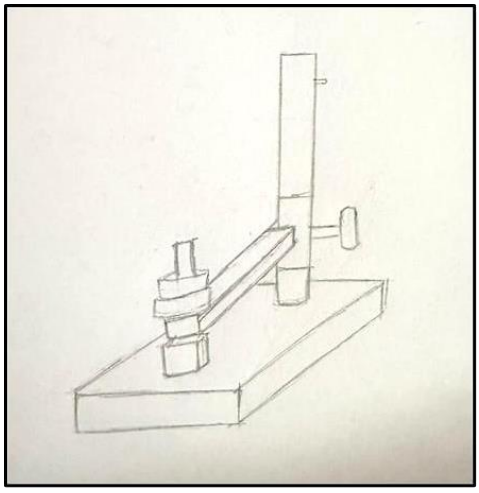

Figure 6: Concept Design 3

2.3 Pugh Matrix

The Pugh Method, also known as Pugh Concept Selection or the Pugh Matrix, is a structured decision-making tool used to evaluate and compare multiple design options against a set of key criteria. Its primary purpose is to identify the most effective design solution by objectively

weighing each option's strengths and weaknesses. In this project, the selection of criteria Safety, Portability, Accuracy, and Cost was made based on the specific needs and challenges observed during the development of the nut knocking jig at IQM. As shown in Table 1, these four criteria were chosen because they directly influence the performance and practicality of the jig. Safety is essential to protect the operator from potential injuries caused by sharp edges or improper handling. Portability ensures the jig can be easily moved and adapted to different workstation layouts. Accuracy is critical to ensure that nuts are removed cleanly without damaging the threads or surrounding components. Cost was included to evaluate the feasibility of manufacturing and implementing the design. The three design alternatives were then compared using a scoring system, where each design was rated as +1 (Good), 0 (Neutral), or -1 (Not Good) for each criterion, as explained in Table 2. By systematically applying this method, the final design selection was made based on clear, objective evaluation rather than subjective judgment, supporting the project's goals of improving efficiency, reducing errors, and enhancing quality on the assembly line.

Table 1: Design Criteria

Criteria	Design 1	Design 2	Design 3
Safety			
Portability			
Accuracy			
Cost			
Weight			

Table 2: Legend of Criteria

Legend	
-1	Not Good
0	Neutral
+1	Good

3.0 RESULTS AND DISCUSSION

This section presents the findings derived from identifying the problem and evaluating potential solutions through comprehensive analysis. To objectively compare and select the best concept design, the Pugh method a systematic approach for concept evaluation was employed. Each proposed design was carefully assessed against predefined criteria, including safety, speed, and weight. Following this thorough evaluation, the design that scored highest and best satisfied the established criteria was selected as the final solution.

3.1 Design Analysis

Table 3 presents the comparison of three different design concepts for the nut knocking jig using the Pugh Method, based on four key criteria: Safety, Portability, Cost, and Accuracy. Each design is scored using a scale of +1 (Good), 0 (Neutral), and -1 (Not Good) depending on how well it satisfies each criterion. The Weight row indicates the relative importance of each criterion in the evaluation process, which was also rated using the same scale. In this project, Safety and Accuracy were given higher importance because they directly affect operator protection and ensure that nuts are removed cleanly without damaging the thread with two

crucial concerns on the IQM production line. Design 3 received positive scores across all four criteria and aligned well with the assigned weights, especially in Safety and Accuracy, making it the most effective and practical option with a total score of 5. On the other hand, designs 1 and 2 scored lower (total score of 1 each) due to poor performance in either cost or safety, which are vital factors in an automotive assembly environment. This table illustrates how the Pugh Method helped select the best nut knocking jig design based on a structured evaluation that balanced performance, practicality, and production requirements.

Table 3: Design Criteria Decision.

Criteria	Design 1	Design 2	Design 3
Safety	-1	-1	+1
Portability	+1	+1	+1
Cost	-1	-1	+1
Accuracy	+1	-1	+1
Weight	-1	-1	+1
Total	2	1	5

3.2 Final Design

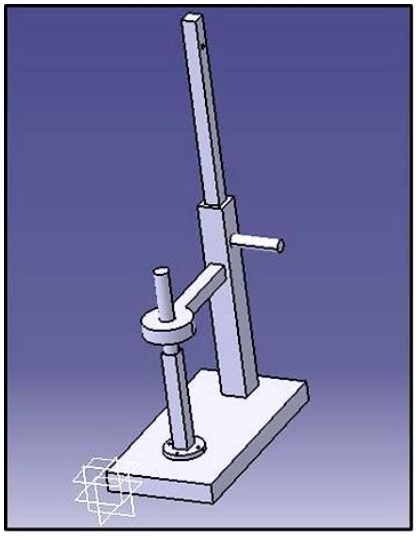

Figure 7: Final Design using Catia V5.

By applying the Pugh Matrix method to evaluate the concept designs, Design 3 was identified as the most favorable option and selected for modeling in CATIA V5. Its portable and lightweight construction enhances ease of handling and mobility. Additionally, the design simplifies the process of inserting parts, reducing preparation time for operators prior to spot welding. A key benefit is the absence of sharp edges, which enhances operator safety by minimizing the risk of injury. Furthermore, its straightforward design allows for easy use without extensive training.

Figure 8: Nut Knocking Jig after being fabricated.

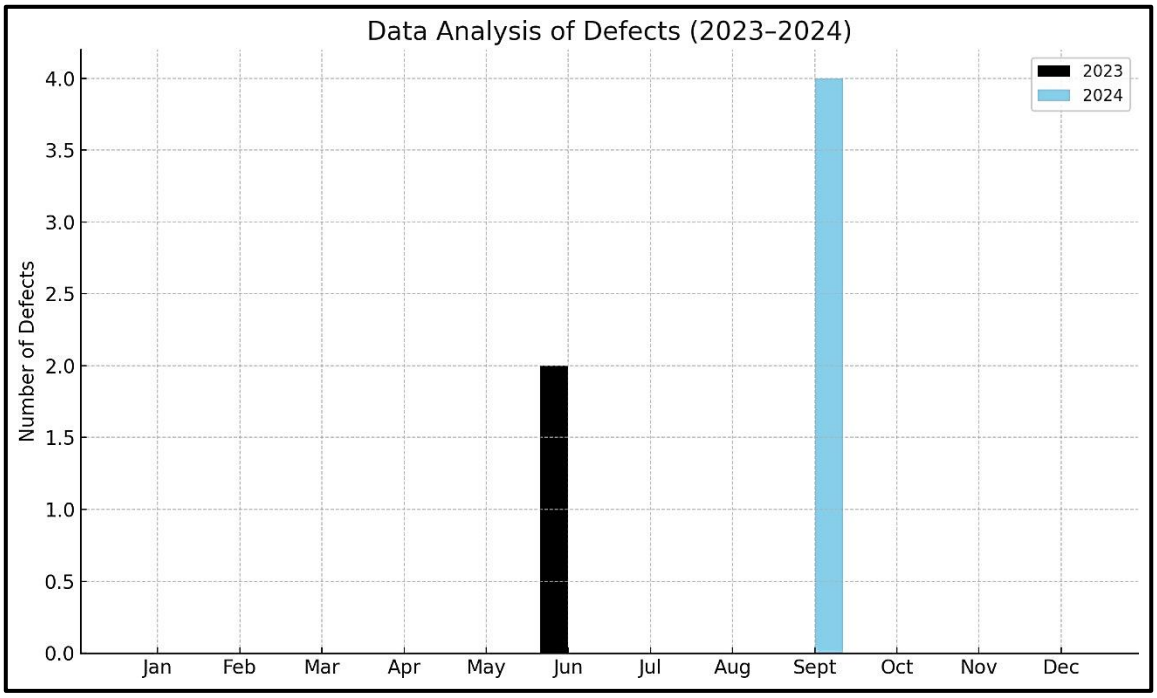

Figure 9: Defect rate Before implementing new nut knocking jig

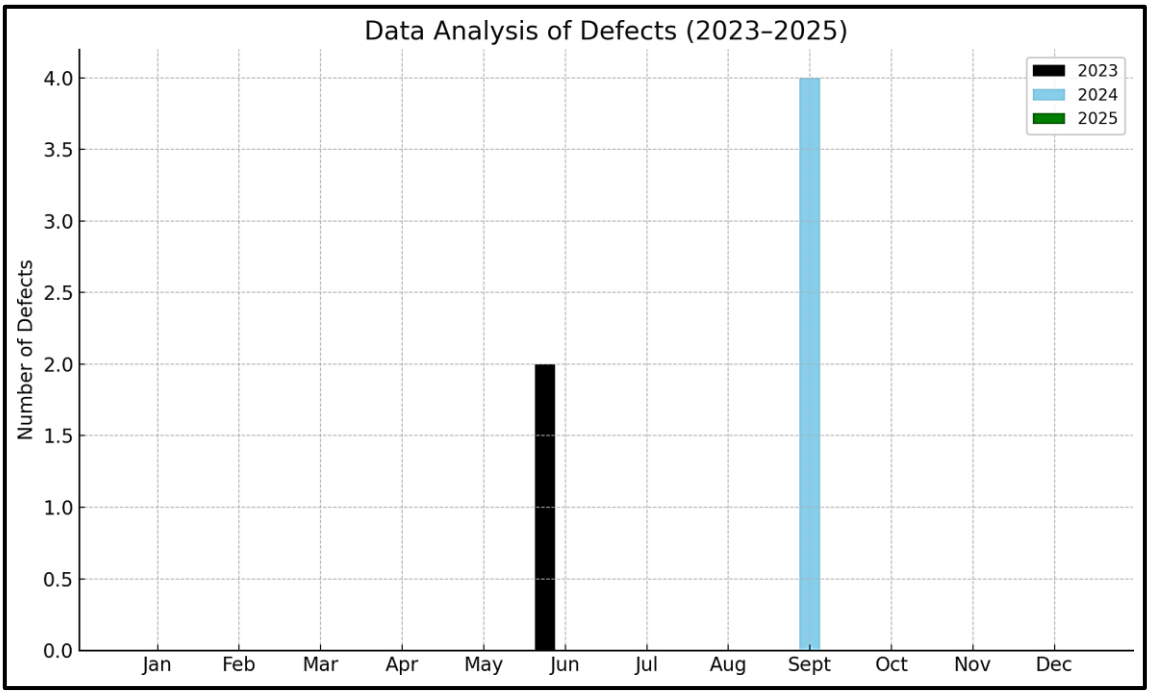

Figure 10 Defect rate After implementing new nut knocking jig

Figure 9 presents data collected over a one-year period before the implementation of the new nut knocking jig, during which Company Y placed an annual order of 71,880 units of Part X. In comparison, Figure 10 shows the data from the year following the jig's implementation, with the same demand of 71,880 parts. Before the new jig was introduced, a total of 6 defective parts were recorded between 2023 and 2024. Although this number may appear minimal, each defective unit cost 30%, resulting in a monthly loss of 50% that Company A had to absorb to fulfil the full order quantity for Company B by following the adoption of the new nut knocking jig, the defect rate was reduced to zero, clearly demonstrating its effectiveness in improving weld precision and product quality. This not only eliminated the need for defect replacement but also contributed to operational cost savings. The investment in the new jig has proven to be highly beneficial, enabling Company A to enhance manufacturing reliability, minimize waste, and avoid recurring losses ultimately supporting better performance and customer satisfaction in the supply chain.

4.0 CONCLUSION

Company B initiated a project to improve its spot-welding process in response to ongoing inefficiencies caused by the existing manual method, which relied heavily on operator strength and often resulted in compromised precision and alignment. Driven by a commitment to innovation and high product quality, the project aimed to optimize the production of metal and plastic components supplied to Company B. Recurring issues such as part misalignment and welding defects highlighted the need for a more efficient solution, prompting the redesign of the hand jig using CATIA V5 software. The development process followed a structured methodology, beginning with problem identification, followed by concept generation and evaluation using the Pugh Method to ensure an objective comparison of design alternatives. Design 3 was ultimately selected for its lightweight structure, ergonomic features, and enhanced safety elements, making it easier to use while reducing the risk of injury. After implementing Design 3, the number of defective parts dropped significantly from six reported

cases in 2023–2024 to zero, demonstrating a major improvement in product quality and process reliability. This testing performance nut knocking jig not only improved the accuracy and efficiency of the spot-welding process but also contributed to significant cost reductions, reinforcing Company B's commitment to delivering high-quality components with minimal waste and rework.

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Design and Fabrication of Racking for Part Reinforcement Sub Assembly, Roof Panel to Optimize Productivity at Quality Gate Workstation

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ABSTRACT

This project presents a thorough analysis of the design of a new racking system for the Reinforcement Sub Assembly Roof Panel at the Quality Gate workstation. The old racking system, which employed a simple hydraulic lift, resulted in inefficient material handling and put significant physical strain on workers. To address these problems, the project used systematic design assessment approaches such as Gemba Walk observations, manpower, machinery, methods, and materials (4M analysis), the 5 Whys root cause analysis, and the Pugh Matrix for idea selection. Three design possibilities were suggested and evaluated against critical criteria such as safety, cost, usefulness, and weight. The most acceptable idea was created with CATIA V5 software and included enhancements such as a lightweight steel frame, rollers for smoother mobility, comfortable handles, wheel locks for stability, and non-slip grips for safety. The study shows that the newly built racking system improves productivity, decreases worker fatigue, and promotes lean manufacturing processes in a more suitable way.

Keywords: racking system, design, pugh method, manual material handling

1.0 INTRODUCTION

This report investigates the present situation of the racking system used for the Reinforcement Sub-Assembly Roof Panel at the Quality Gate Workstation. The present racking system has been recognized as a cause of inefficiency, resulting in longer production process movement and workflow disruptions during the manufacturing process. These challenges originate from restricted mobility, instability, and incompatibility with the existing workstation arrangement, all of which hinder smooth component handling and transfer. The assembly process requires workers to manually handle and move pieces using the present racking, which lacks characteristics that allow for easy mobility and stable placing. This causes delays and greater operator effort, reducing overall productivity. To address these challenges, this project focuses on redesigning and fabricating a new racking system that improves stability, accessibility, and compatibility with existing processes. The redesigned racking aims to enhance material handling efficiency, reduce workflow interruptions, and support smoother operations at the Quality Gate workstation.

1.1 Problem Statements

The current racking system used for the Reinforcement Sub-Assembly Roof Panel at the Quality Gate workstation presents several challenges that hinder smooth production flow. The existing design lacks sufficient stability, accessibility, and mobility, which complicates the handling and transfer of components during assembly. These deficiencies contribute to workflow interruptions and increased operator effort. To address these issues, it is essential to redesign the racking system to better support the assembly process. This study aims to develop a new racking design that enhances stability, improves accessibility, and integrates seamlessly with existing workstation processes.

Additionally,the project involves fabricating the redesigned racking system to validate its functionality and suitability for the production environment. By focusing on these objectives, the project seeks to provide a practical solution that facilitates smoother material handling, reduces operational difficulties, and supports overall productivity improvements at the Quality Gate workstation. Figure 1 shows the current racking at the quality gate workstation.

Figure 1: Current racking used at the quality gate workstation.

1.2 Objective

- To design the production racking to improve process movement for Quality Gate workstation.

1.3 Literature Review

1.3.1. Material Handling

Material handling is the movement of parts or products within a factory. It can be done manually, with tools like trolleys and lifts, or through automated systems like conveyors and robots. In this project, manual handling is improved by using redesigned racks with wheels and handles. This reduces worker fatigue, improves safety, and shortens production time (Skals et al., 2021). It also helps prevent product damage and boosts efficiency. Observations and a Gemba Walk showed that the current handling methods were slow and inefficient. The new rack design allows safer and faster movement between the workstation and storage, improving overall productivity at quality gate workstations.

1.3.2. Racking Systems

Racking is important in factories for storing and moving parts. Old racks are often fixed and hard to move. Modern racks have rollers, wheel locks, and handles to make moving parts easier and faster. Some even adjust to different part sizes or work with robots. Good rack design improves safety, space use, and organization (Okur, 2024). In this project, the rack is redesigned with rollers, handles, brakes, and non-slip grips to make handling safer and easier. The current racks at IQM don’t have these features, causing delays. The new design helps speed up work and reduces the need for lifts.

1.3.3 Design Software – CATIA V5

CATIA V5 is a CAD (Computer-Aided Design) software used to create 3D models of mechanical parts. It helps engineers see and test the racking system before making it (Daneshjo, Malega, and Drábik, 2021). CATIA makes it easier to design with accurate sizes, reduce errors, and check for safety and usability. In this project, CATIA was used to compare three rack designs and choose the best one. It allowed precise control of dimensions and part placement, helping ensure the final design fits the needs of the workstation.

1.3.4 Pugh Matrix (Decision Making Tool)

The Pugh Matrix is a tool used to compare design options based on factors like cost, safety, ease of use, and maintenance. Each option is rated against a base design, and the one with the highest score is chosen (Okuyucu and Tanik, 2023). In this project, three rack designs were compared using the Pugh Matrix. Design 1 scored the highest and was selected for fabrication. This method helped make a clear and fair choice during the design phase.

1.3.5. Kaizen (Continuous Improvement)

Kaizen is a Japanese idea that means "change for the better." It focuses on small daily improvements to reduce waste and improve work (Syaputra and Aisyah, 2022). In this project, Kaizen was used to improve the existing rack design to reduce delays and make handling easier and safer. The team gathered feedback from workers during the early stages and used it to guide the changes. These small improvements led to less manual effort.

2.0 METHODOLOGY

This section outlines the methods used in this project to design and fabricate an improved racking system. One key method employed is the Pugh matrix, which was instrumental in selecting the optimal design from multiple proposed concepts. The Pugh method is a systematic decision-making technique used in engineering design to evaluate and compare different design concepts against baseline design. In this project, it facilitated the objective assessment of various racking system designs, ensuring the selection of the most viable option based on predetermined criteria.

The Pugh matrix allowed for a structured comparison of the proposed racking system designs, considering factors such as stability, accessibility, material utilization, and compatibility with the existing workstation. By evaluating each design relative to a baseline design, the Pugh matrix helped identify the strengths and weaknesses of each option. This iterative process enabled the refinement of concepts and the selection of a final design that best met the project's objectives.

The selected racking system design was then translated into a physical product through fabrication, following established engineering practices and quality control measures. The fabrication process involved material selection, cutting, welding, and assembly, with adjustments made as necessary based on feedback from the design and workshop teams. To visualize the project workflow, a flowchart illustrates the steps involved, from initial problem identification to final fabrication and implementation. This structured methodology ensured a systematic and efficient approach to the design and fabrication of the improved racking system. Figure 2 shows the flowchart of the process.

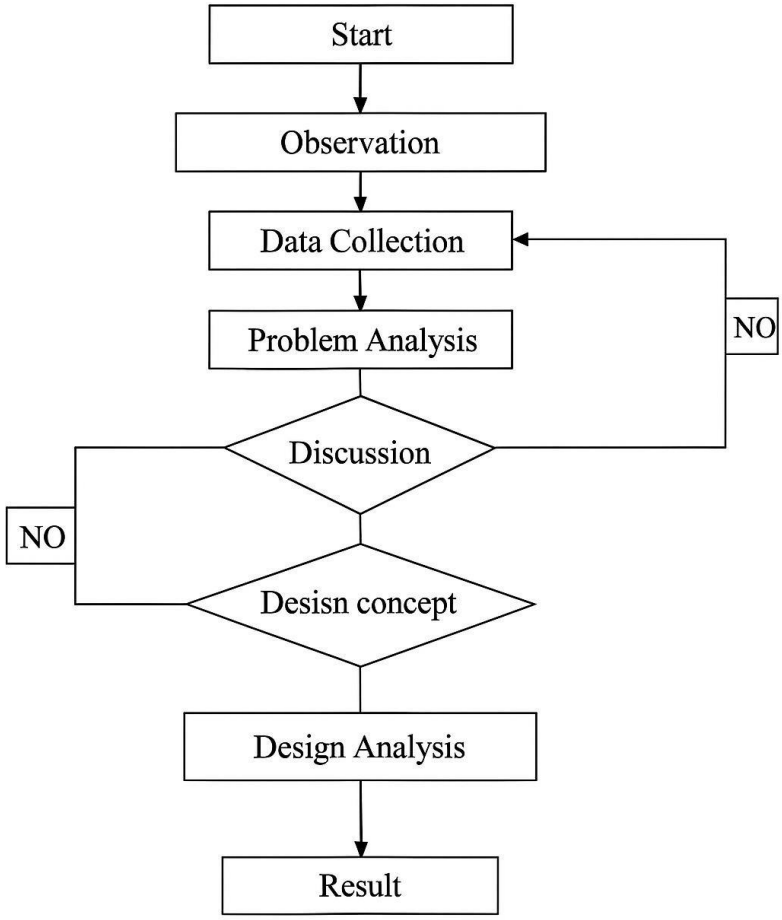

Figure 2: Flowchart of framework

In this paper, the main idea and concept is using the PDCA. PDCA state for plan-do-check-act. Where the research starts with planning follow with do and check, and act.

2.1 Observation Method (GEMBA WALK)

The Gemba walk method is crucial to find the root cause of the problem and to find the data for the analysis since these methods ask use to go and walk throughout the entire place and with these, we can collect the required data for it. Doing a Gemba walk, or regular workshop visits is one of the finest ways to identify issues within the organization and engage with employees to find suggestions for solutions. Successful Gemba walks require a clear plan so that staff members may prepare for the visit and prevent any unpleasant shocks. Observing people's activities and introducing oneself with the technological equipment and production process were the goals of the initial walks (Mičieta et al. 2021). The questions weren't directed at the staff; they were purely instructive. Gemba's walks also aimed to build connection with staff members through direct communication to gain their trust.

2.2 Design Research

The improvement design will draft the idea at the paper about two and more ideas and propose to the supervisor. After that, we will check the draft and select the best idea design that has been proposed. After approval, we will design the idea that has been selected through the 3D software and referring to the 3D data from the draft. The design created by using software Catia V5(Okur 2024). This Pugh method was chosen because having an example of study was successful when using this method like. Figure 3 shows the design concept in sketching.

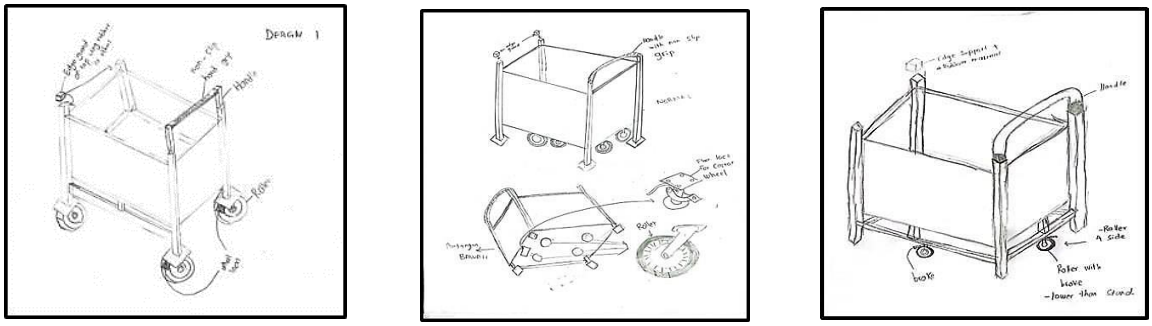

Figure 3: Design 1,2 and 3

The figure illustrates three proposed designs for a new racking to improve Reinforcement Sub Assy, Roof Panel process. Design 1 is higher than the others because the roller was mounted at the base of the racking or should be said as stand. Design 1 using roller that was already applied with the brake at the front of the racking that at the same line as holder to make it easier to brake and this higher design was able to reduce the backpain of the workers when using it. Design 2 includes the roller at the base or the floor under body that makes the body of the racking lower than needed and the roller and floor stand are separated on this design because the height of the floor stand is good already and does not need any adjustment. Design 3 placed the roller beside the body that can be seen, and the brake was placed under the floor and the same as design 2.

2.3 Pugh Method

The Pugh matrix, created by Stuart Pugh, who led the design division and was a professor at the University of Strathclyde in Glasgow, goes by many names. These include the Pugh method, Pugh Analysis, Decision Matrix Methods, decision grid, selection grid, selection matrix, problem matrix, problem selection matrix, problem selection grid, solution matrix, criteria rating form, criteria-based matrix, and opportunity analysis. This matrix is used for decision-making to help choose the most viable and feasible option from a list of alternatives. To do this, you first need to determine the most important criteria for making the decision. Then, you evaluate each alternative based on these criteria to select the best one. While both teams and individuals can use this method, it is often more effective when used by teams.

An interesting approach in team decision-making is for each person to create their own Pugh matrix. The team then compares these matrices. A Pugh matrix is typically used to evaluate several alternatives to choose the best option. It can also be used when there is only one solution, helping to optimize it for the best results. (OKUYUCU and TANIK 2023). Table 1 shows the criteria for the score.

Table 1: Legend of criteria

Legend	
-1	Not Good
0	Same
+1	Good

2.4. Method:

4M Method (Man, Machine, Material, Method) (Daneshjo et al. 2021):
Analyzed deficiencies across four factors:

- Man: Lack of trained staff and long working hours.

- Machine: Outdated and poorly maintained hydraulic lifts.
- Material: Heaviness and bulkiness of parts.
- Method: Inefficient procedures for loading and unloading parts.

2.5 5 WHYS

The 5 Whys method is crucial to find the root cause of the problem on most of the process happen on all the thing happening around such as at manufacturing sector, health sector, management sector and others. These methods were used to find the most possible cause and action required to solve the problem based on the question. For the use of this method in this project is to find the root cause of why the process movement of using the racking that move using the small hydraulic lift is not truly efficient for the production process at the quality gate workstation.

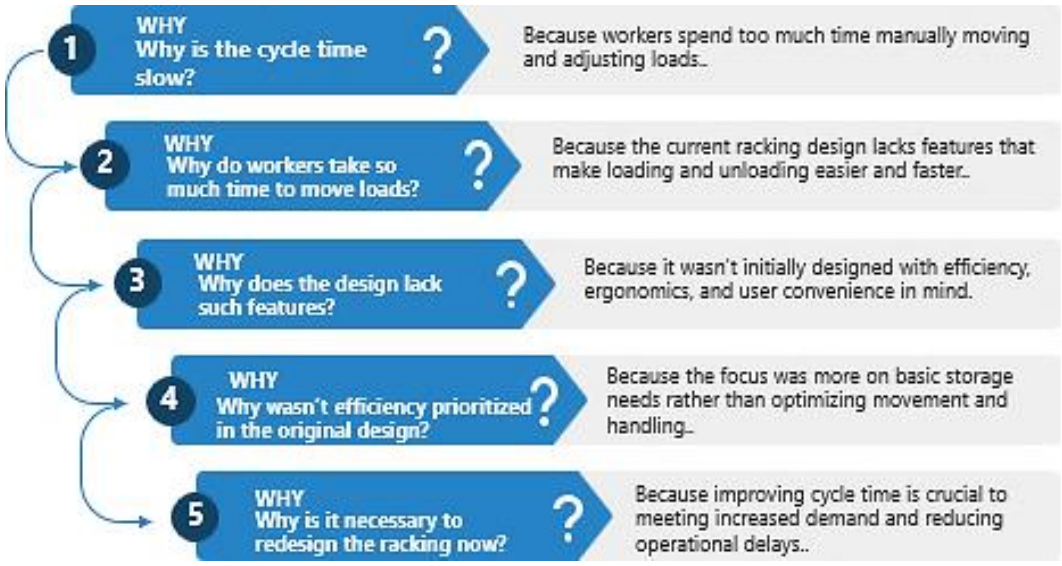

Figure 4: 5 Whys Method for Current Racking

3.0 RESULTS AND DISCUSSION

The Results and Data Analysis section of the study examines the results of different approaches and analyses used to tackle issues in the product process at company. The party seeks to provide thorough knowledge of the project's CONCLUSION by conducting detailed analyses such as the Pugh method. The text delves into the effects of design interventions and automation on production efficiency. The section will provide important information on the success of implemented solutions and their implications for optimizing production processes.

3.1 Design Analysis

As one can see in Table 4, Design A recorded the highest score, 5 points, mainly because it achieved a high score in Efficiency and Performance, which were weighted most. It also performed well in Safety to bag the number one spot. Design C was next with 4 points, giving balanced results but lacking in certain aspects. Design B, minimum scoring for 4 points had been less effective because of the poor rating of Efficiency and Safety.

Table 2 Racking rating for categories

Criteria	Design 1	Design 2	Design 3
Safety	+1	+1	+1
Cost	+1	0	+1
Weight	+1	+1	+1
Ease of use	+1	+1	0
Maintenance	+1	+1	+1
Total	5	4	4

This section describes the results of the modifications made to the quality gate workstation. The focus is on evaluating and comparing three rack designs using the Pugh approach to identify the best design in terms of safety and weight. Three rack designs were assessed using the Pugh approach. Design 1 was used as a reference and received the highest overall score. It was ranked the safest because of its ergonomic height, user-friendly roller system, and built-in brake, all of which contributed to decrease worker strain and increase overall performance.

Design 2 had issues with roller placement, making part movement less stable and more difficult to control. Design 3 had the lowest height, which forced operators to bend frequently, increasing physical discomfort and reducing efficiency. In terms of weight, Design 1 had the lowest value. Its structure was optimized for strength while minimizing unnecessary material, making it easier to handle during movement and installation. Designs 2 and 3 had higher weight due to added components and less efficient construction.

Based on the evaluation, Design 1 was selected as the most suitable option. Its high safety performance and lower weight make it ideal for improving productivity, reducing physical strain, and enhancing worker comfort at the quality gate workstation.

3.2 Final Design

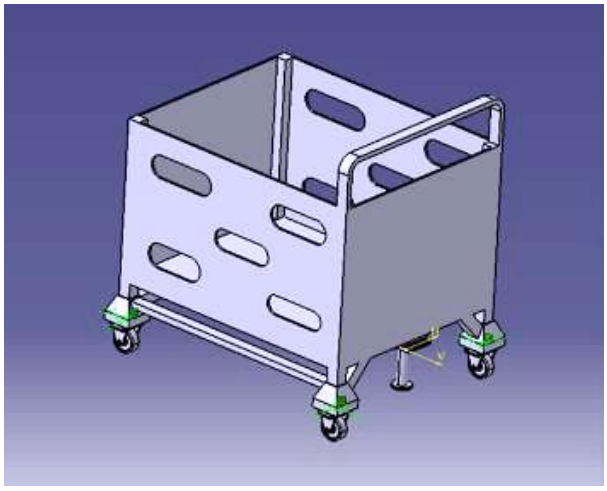

Figure 5: Final Design

4.0 CONCLUSION

The redesign and fabrication of the racking system for the Reinforcement Sub-Assembly Roof Panel at the Quality Gate workstation successfully addressed the key issues of instability, poor

accessibility, and inefficiency found in the original system. By applying systematic methodologies, including the Pugh method, Gemba walk, 4M analysis, and the 5 Whys technique, the project identified root causes and developed targeted solutions. Among the three proposed designs, Design 1 was selected for its superior performance in safety, cost-effectiveness, ease of use, and overall ergonomic benefits. The newly implemented racking system led to a significant reduction in process movement. This project not only improved workflow efficiency and operator comfort but also demonstrated the value of structured problem-solving and design thinking in optimizing manufacturing processes.

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Syaputra, Muhammad Julian, and Siti Aisyah. 2022. *Kaizen Method Implementation in Industries: Literature Review and Research Issues*. Vol. 3.

Design of Low Cost Karakuri Rack Box at Sub-Assembly Workstation

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ABSTRACT
Karakuri rack is a stored mechanism that used zero electricity and rely on natural gravity. The method of karakuri used in Japan for low costing mechanism in manufacturing industry. At the sub-assembly workstation in Plant 2 of Company Z Sdn Bhd arises from the lack of a proper Work-In-Progress (WIP) storage system near the workstation. This inefficiency disrupts workflow, as operators must spend excessive time and effort locating and retrieving materials. This project aims to design low cost a WIP Karakuri rack box that ensures easy access and better organization using simple mechanical principles. The methodology for this research are 5 whys, catia software, costing table, pugh matrix. Catia software for designing the storage system and produce bill of material to analyze in costing table. A Pugh Matrix analysis will guide the selection of the most cost-effective design. The result finding are, design C was selected due to cost effectiveness and simple design in assembling. Design C cost RM 160 to fabricate and consumed minimal of time which is 3.95 hours total completion of fabrications. This significant finding are following the pugh matrix criteria and project objective which is to design low cost karakuri rack.

Keywords: karakuri rack, 5 whys, Catia software, Pugh matrix, , cost effectiveness.

1.0 INTRODUCTION

In Plant 2 of Company Z Sdn Bhd, unorganized WIP placement at the sub-assembly workstation occurs due to the absence of proper WIP storage rack boxes near the workstation. Without a designated and organized storage system, operators spend unnecessary time and effort moving around to locate and retrieve materials which resulted confusion among operators Karakuri is a method from Japanese terms which is mechanics without electric or fluid consumption. The functions of karakuri rack in industries are for storing purposes and designed to create organized environment. Based on past research by Kostrzewski, M., Nowak, W.J. (2022). Karakuri Solutions and Industry 4.0, selected solutions, based on karakuri principles, work more effectively than complex and expensive.

1.1 Objective
The objective of the project is to design low cost karakuri rack. The design process are the main goals for fabrication to installed in sub-assembly workstation.

1.2 Problem statement
Figure 1 shows that unorganized environment in Sub-Assembly workstation at Company Z Sdn Bhd. Unorganized environment could create confusion among the operators in Sub-Assembly workstation and can lead to error in producing specific products that needed to produce.

Figure 1: Unorganized WIP box environment in Sub-Assembly workstation

2.0 METHODOLOGY

The methodology for designing a karakuri rack box at the sub-assembly workstation aims to fabricate low cost karakuri rack through lean tools and engineering design. It begins with the 5 Whys Root Cause Analysis to identify the root causes of the problems. Afterwards, begin in sketch design to evaluate ideas of fabrication should be shaped.The sketch design will convert into Catia V5 in producing bill of material drafting. The begin of Pugh Matrix analysis is after bill of material drafting, to ensure right decision to be made in fabricating low cost karakuri rack box. The criteria of pugh matrix analysis will consist, fabrication completion time and fabrication costing with reference of material market in Malaysia.

3.0 RESULTS AND DISCUSSION

In this chapter, 5 WHYS root cause analysis is the main solution ideas breakthrough to countermeasure root of the problems. The result should be truthful towards the data needed in completion, as it may needed a person to guiding in giving answer through the 5 Whys question. In order to complete the project, the core result of this project are pugh matrix analysis and finalization. Pugh matrix helped to give insight in decisioning, although the decision may required with the criteria set. The criteria are fabrication completion time and fabrication costing. Lastly is, the finalization of the design in fabricating. The finalization must be chosed based on the highest scores of pugh matrix analysis, it may seems that the right designed may not good as it think.

3.1 5 WHYS

5 WHYS?

	1	2	3	4	5
WHY?	Why operator walk out from Sub-Assembly to retrieve WIP material	Why all WIP material outside from Sub-Assembly area	Why no space in Sub-Assembly workstation	Why unogarnized WIP box placement	Why no designated storage equipment in workstation
REASON	Because all WIP material outside from Sub-Assembly area	Because no space in Sub-Assembly workstation	Because unorganized WIP box placement	**Because no designated storage equipment in workstation**	**Because no fabrications due to cost saving**

Figure 2: 5 whys table and reasoning

The figure 2 shows result of 5 whys root causes analysis. The tools conducted by 2 person which is consist questioning and answering. The questioning made by the author Muhammad Azeem and the reasoning answer made by En.Azlan , the production engineer in company Z Sdn Bhd. The 1st and 2nd why were made during full thesis paper that related with this project, the thesis tittle are Designing and Installing Low Cost WIP Karakuri Rack Box Storage in Sub-Assembly workstation to reduce motion waste. The red highlighted box were focused based on why are the rootcause of unorganized WIP box placement. The result of the rootcause are no fabrications due to cost saving in Company Z Sdn Bhd.

3.2 Sketch Design

The designing phase started with 3 sketch design which is sketch design A,B and C. The result shows, tools of visualization before converting to Catia V5 software in producing bill of material drafting.

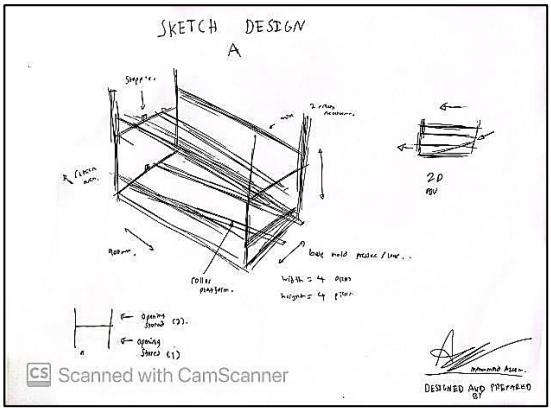


Figure 3(i): Design sketches A

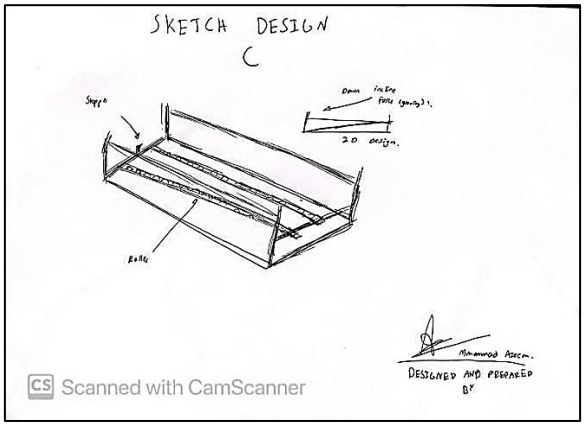


Figure 3(ii): Design sketches B

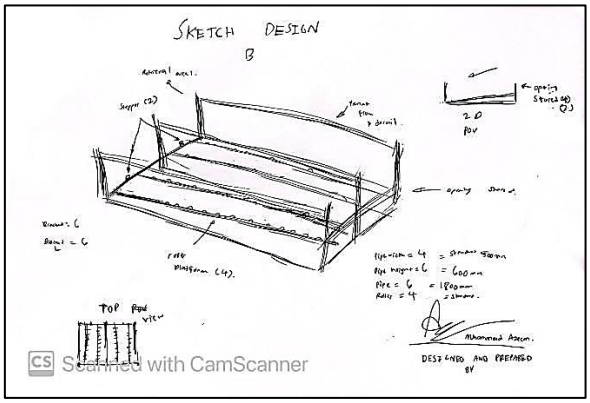
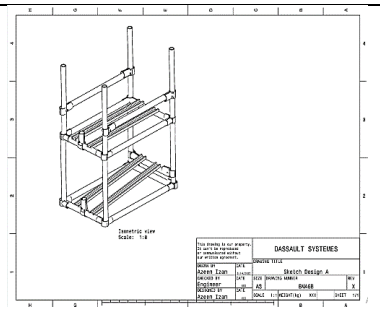
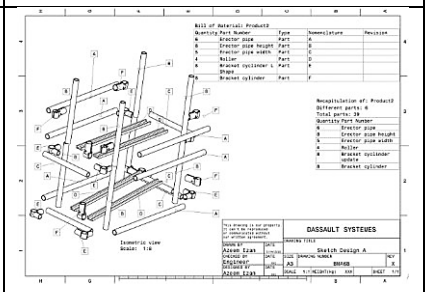
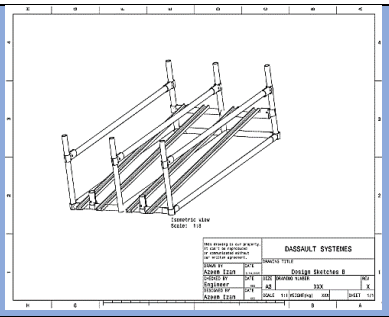
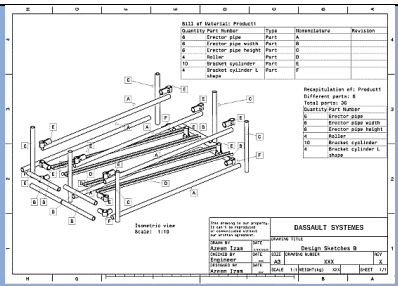
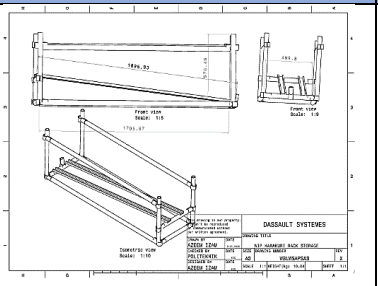
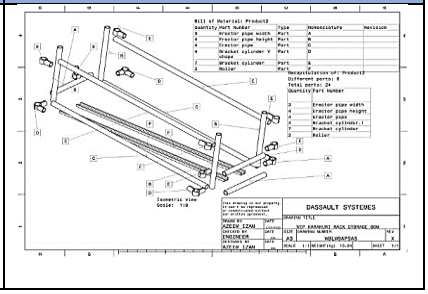


Figure 3(iii): Design sketches C

3.3 Catia V5 Drafting

Table 1: Catia drafting and BOM drafting based on sketch design.

No	Sketch Design	Catia Drafting	BOM Drafting (Catia)
1	A		
2	B		
3	C		

The table 1 shows result of design sketches A,B and C drafting converted into Catia V5 software in producing bill of material drafting. The result bill of material of the three design

which is A,B,and C, remarkably design C has the lowest total child parts which is 24 child parts. The most highest total childparts resulted is design A which is 39 total child parts. This can acknowledge that, it cant be judges by the sketches of the simplest design using own eye. The of Catia V5 proven in bill of material needed to used among the three design sketches in calculating how much the total child parts needed to purchase in fabricating low cost karakuri rack in sub-assembly workstation.

3.4 Pugh matrix analysis

NO	DESIGN SKETCHES	Parts	Quantity	Prep Time (min)	Assembly Time (min)	Total Child parts	Fabrication time completion
1	A	Erector pipe	19	2	5	39	397 min =6.61 hours
		Bracket cylinder	16	7	7		
		Roller platform	4	2	8		
2	B	Erector pipe	18	2	5	36	362 min= 6.03 hours
		Bracket cylinder	14	7	7		
		Roller platform	4	2	8		
3	C	Erector pipe	11	2	5	24	237 min= 3.95 hours
		Bracket cylinder	11	7	7		
		Roller platform	2	2	8		

Figure 4: Fabrication completion of 3 design sketches

The calculation of fabrication time completion were inspired from past researches which is by Adel, M., Allam, A., Sayour, A. E., Ragai, H. F., Umezu, S., & Fath El-Bab, A. M. R. (2023). Fabrication of Spiral Low-Cost Microchannel with Trapezoidal Cross Section for Cell Separation Using a Grayscale Approach. Micromachines.

tb=f(T,F,d,M,E)
Where:

- tb = Bonding time (fabrication completion time)
- T = Bonding temperature
- F = Applied force
- d = Thickness of the sheets (e.g., 2 mm)
- M = Material properties (e.g., PMMA characteristics like Tg, melting point)
- E = Environmental factors (e.g., oven type: natural or forced ventilation)

This is not a strict mathematical formula, but rather an expression that bonding time depends on these parameters.

In the meantime, the calculation by the past researcher were convert into manufacturing principle in calculation total fabrication completion time in achieving project with a tight deadline.

tb=f(T+F+M)
Where:

- tb = Total (fabrication completion time)
- f = Quantity parts
- T= Prep time (min)
- M= Assembly time (min)

NO	Design Sketches	Parts	Quantity	Cost (RM)/unit	Total Cost	Grand Total Cost
1	A	Erector pipe	19	30	150	RM 282
		Bracket Cylinder	16	2	32	
		Roller platform	4	25	100	
2	B	Erector pipe	18	30	135	RM 263
		Bracket Cylinder	14	2	28	
		Roller platform	4	25	100	
3	C	Erector pipe	11	30	90	RM 160
		Bracket cylinder	10	2	20	
		Roller platform	2	25	50	

Figure 5: Fabrication total cost in 3 design sketches

Figure 5 above shows result from bill of material drafting in costing to purchases. The core of this table help to figured costing purchases in decision making which is called pugh matrix analysis by total costing criteria. The result found that, design sketches C is the cheapest among the 3 design which is only cost RM 160 to fabricate. The most expensive grand total costing is design sketches A which is costly RM 282. This significant result enhanced in decision making towards to fabricate low cost karakuri rack in sub-assembly workstation. In addition, all estimated pricing of the parts are the actual value finding in Malaysia market.

3.6 Finalizations

NO	Design Sketches	CRITERIA	SCORES	TOTAL SCORES	MAX SCORES
1	A	Fabrication completion time	2	5	10
		Fabrication costing	3		
2	B	Fabrication completion time	2	5	10
		Fabrication costing	3		
3	C	Fabrication completion time	3	7	10
		Fabrication costing	4		

No	Fabrication completion time	Scores
1	<400min	1
2	>400min	2
3	>300min	3
4	>200min	4
5	>100min	5

No	Fabrication costing	Scores
1	<RM400	1
2	>RM400	2
3	>RM300	3
4	>RM200	4
5	>RM100	5

Figure 6: Pugh matrix finalization in 3 design sketches with reference criteria scores

Figure 6 above shows that result from pugh matrix analysis in decision making towards fabrications of low cost karakuri rack box storage in sub-assembly workstation. The result of the scores reference are shown in previous pages which is in figure and figure. All design sketches of A,B,and C were judges based on total scores of 2 criteria which is fabrication completion time and fabrication costing. The result shows, design sketches C is the highest total scores among 3 design sketches with the total scores of 7/10. The finalizations made in selection design sketches is design sketches C with the total scores of 7/10. The definition scores of finalization are based on criteria made in achieving fabricating a low cost karakuri rack box storage. In addition, the fabrication completion time criteria were used to calculating fabrication completion time in process to end the project early as possible to avoid any errors and tight deadline.

3.7 Discussions

3.7.1 Implementation of low cost karakuri rack in sub-assembly workstation

Figure 7: Implementation of design sketches C after fabrications

The figure 7 above shows the implementation of low cost karakuri rack under spraying boot in sub-assembly workstation. This proven that karakuri rack box storage could organized the WIP box in places. In addition, it prevent operator confusion along the process in spraying at sub-assembly workstation.

3.7.2 Fabrication costing

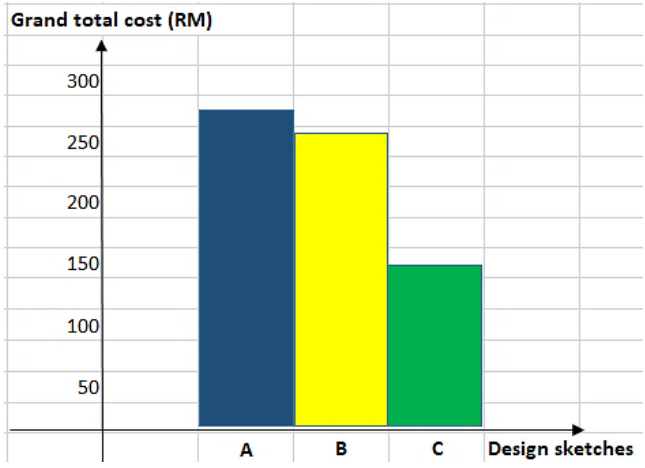


Figure 8: Histogram of comparison in total costing of 3 design sketches

Figure 8 above shows histogram graph in comprise 3 design sketches based on grand total costing in fabrication. As it can see, design sketches C are the cheapest among the 3 design sketches with grand total costing fabrication is RM 160 only. The most expensive cost among the 3 design in fabrication is design sketches A with a grand total costing RM 282. This proven that complex design are the most consumable money in fabricating due to quantity of the child parts needed.

4.0 CONCLUSION

4.1 Sketch design with karakuri element

The sketch design were successfully implement in achieving designing low cost karakuri rack in sub-assembly workstation. First method of the project, sketching in other words is evaluating ideas concept into drawing paper. The design sketch A,B,and C was inputted with karakuri element which is inclining roller platform in karakuri rack design. This proven that, sketch design are the main core of the process starting in achieving designing low cost karakuri rack box design.

4.2 Catia V5 Drafting in producing bill of material

Catia V5 drafting are important to estimate the costing of the material needed based on drafting bill of material. This shows the importance Catia V5 in achieving to design low cost karakuri rack box in sub-assembly workstation because of Catia V5 can provide bill of material to calculate child parts needed and costing. This proven Catia V5 could resulted and achieved in designing low cost karakuri rack box in sub-assembly workstation.

4.3 Pugh matrix in decisioning till finalization

The pugh matrix help in decisioning of design low cost karakuri rack box storage in sub-assembly because of scoring criteria made such as fabrication completion time and costing. The fabrication completion time analyze which of the design sketches fabricate complete in a short time. Costing fabrication analyze the cost of fabrication based on quantity of the child part each design sketches. The highest total score in pugh matrix in finalization is design sketches C. This proven with total scores definition are based by criteria, therefore it achieves in designing the karakuri rack with a low cost and short fabrication time.

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Root Cause Analysis

Design of an Assembly Jig for the Console Top Garnish Panel Assy

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ABSTRACT

This thesis presents the design and development of an assembly jig for the console top garnish panel to improve production efficiency and product quality in automotive interior component assembly. The current manual assembly process faces challenges such as inconsistent positioning, increased cycle time, and a higher risk of surface defects like scratches and paint damage. To address these issues, a dedicated jig was designed using CATIA V5 software, enabling precise alignment and secure clamping of the panel during installation. Several concept designs were generated and evaluated using the Pugh method to select the most effective solution based on criteria such as ease of use, manufacturability, cost, and safety. The selected design was then fabricated and tested for functionality. The implementation of the jig demonstrated a significant reduction in assembly time, improved ergonomic conditions for operators, and consistent product quality. This project contributes to the continuous improvement of production processes by integrating structured design methodology and advanced CAD tools into fixture development.

Keywords: design, CATIA V5, pugh method, fabricate, assembly jig

1.0 INTRODUCTION

This project is the center console for the assembly process console top garnish panel assy, which needs to be studied to produce a flawless product according to the specifications and the customer's requirements. This study aims to design the jig used in process assembly for part console top garnish panel assy to make a fast process in the assembly line. The assembly process for the console top garnish panel assy involves installing clips, electronic components, and a cup holder. This process is currently facing several challenges, none of these parts have an existing assembly jig. As a result, the development team is tasked with studying the requirements and designing an optimized jig for the center console. This jig will play a crucial role in improving assembly efficiency, ensuring precision, and maintaining high-quality standards for assembly process [1].

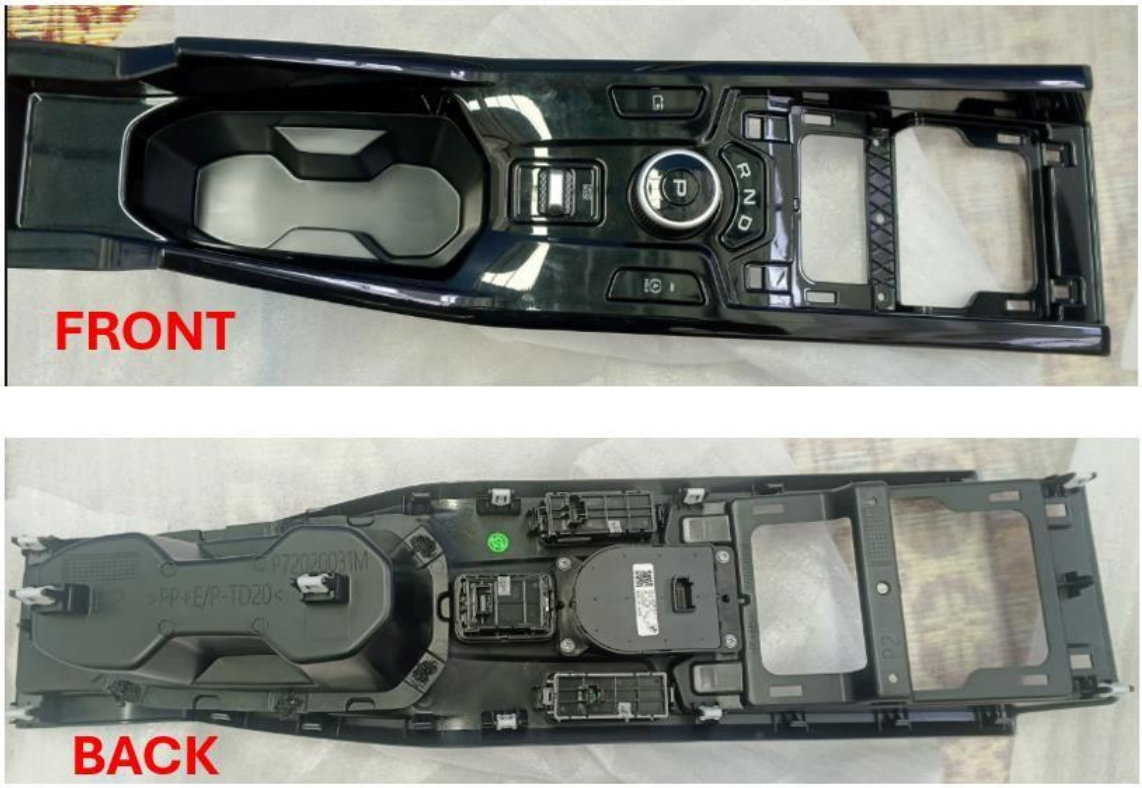

Figure 1: Console Top Garnish Panel Assy

1.1 Problem statement

The console top garnish can break or become damaged during the installation of components such as the cup holder, clips, and electronic parts. This issue arises primarily because the console top garnish is not a flat surface, which creates uneven pressure and stress points during assembly. As a result, the lack of a uniform surface leads to difficulties in properly aligning and securing these components, increasing the likelihood of cracks or wrapping. To mitigate this, design modifications or specialized assembly tools may be required to ensure the durability of the console top garnish and improve the ease of installation.

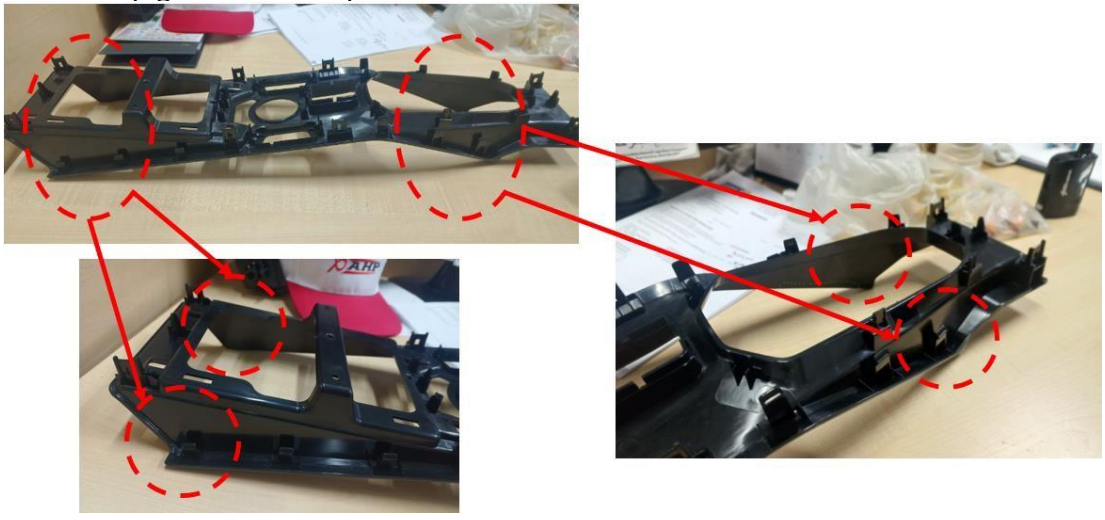

Figure 2: Why part can break and wrapping

Figure 3: Part can wrapping while assembly process.

1.2 Objective

The main objective of this project is:

- ✓ To design a jig for the console top garnish panel that meets all assembly requirements

2.0 METHODOLOGY

2.1 Observation

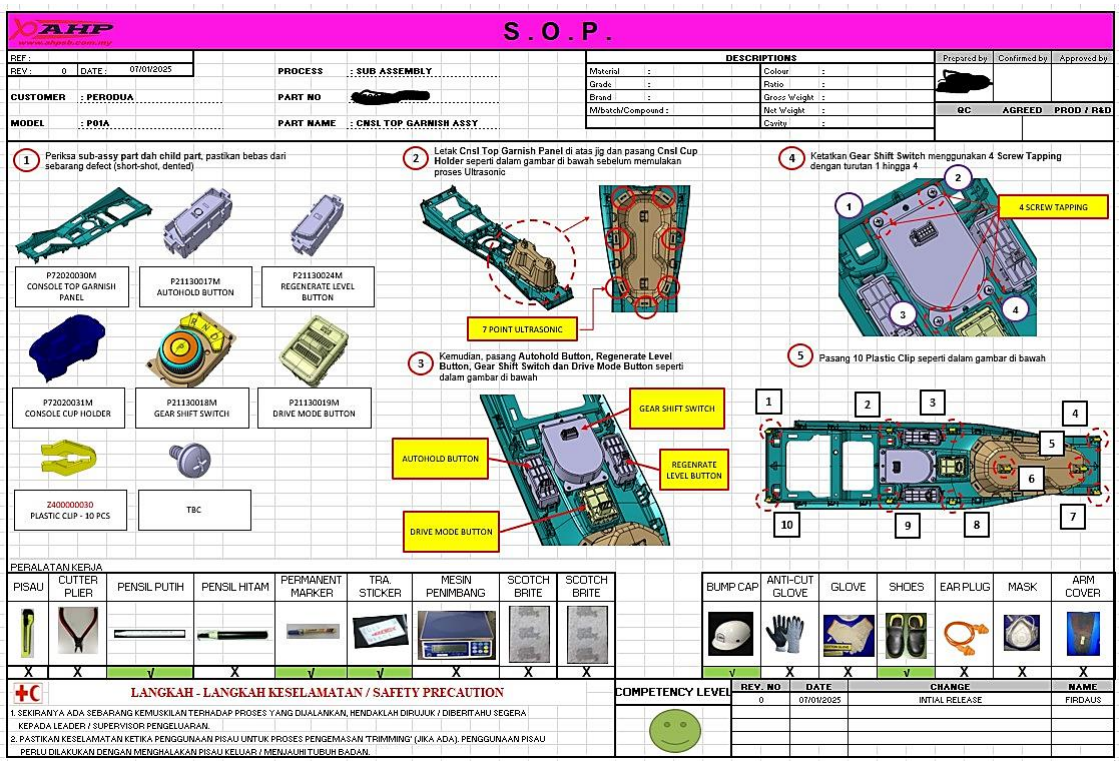

Figure 4: SOP for assembly console top garnish.

The study planning is based on the data collection by observation of the production from the current process [2]. The observation is done at the workstation of the assembly line of center

console. The function of new the jig is to use the assembly as part of the center console assembly. From observing the new jig, the assembly method, the part of center console such as console top garnish, cup holder, electronic part and clip are used in one process assembly. This process is currently facing several challenges, including inefficiencies caused by time-intensive manual handling, frequent errors such as misalignments during clip installation or improper fitting of electronic parts, and difficulties due to repetitive tasks and awkward part handling.

2.2 Brainstorming

The design team will discuss the appropriate idea through brainstorming. The design team will sketch the design idea while brainstorming to develop a solution. The designer must be clear about the problem and understand how the jig operates throughout this step [3]. The jig design must be able to solve the problem that has been described and archived to the next stage with simplicity. The function of the design process must be examined.

2.3 Sketching and 3D design

Concept designing and three-dimensional modeling are critical steps in the product development methodology and act as prerequisites for the formation of viable assembly tools. The first step on this process is the sketching, which involves the creation of ideas in illustrations. These sketches are very helpful to guide the framework and presentation of the jig because it provides a simple yet accurate layout of the jig's design. After the conception of ideas drawn on paper, the artwork is developed by creating precise and detailed computer animated models. In this project, CATIA V5 was used in producing realistic 3D patterns of the jig [4].

2.3.1 Sketching

Probably, the best-known and most frequently used method in designing is a sketch. It is crucial at the beginning of the design stage as it gives the first tangible image of ideas and notions. It enables the designers and engineers to have an opportunity to look for different structures, operations and attributes of a jig before coming up with the final design of the jig. In this case, three different views of the jig have been sketched with the focus of their design being different next.

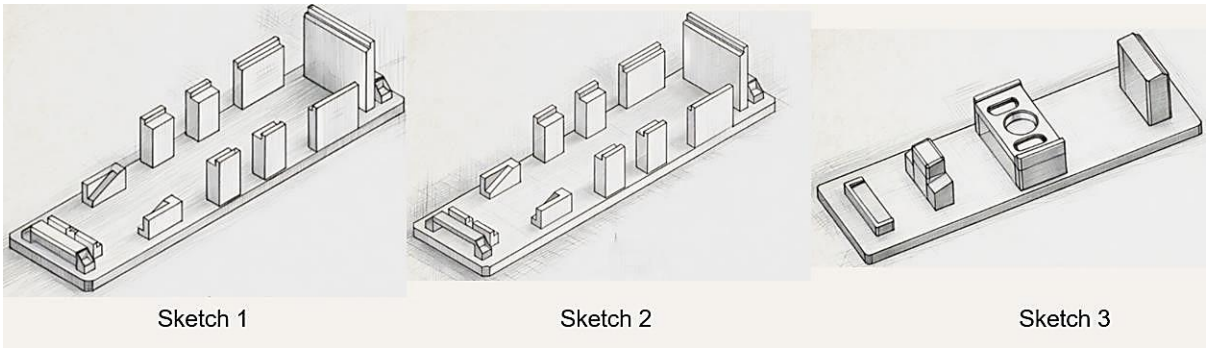

Figure 5: Sketching design

2.3.2 3D design

The 3D design could be seen as the most important stage of the jig development as it allows to illustrate the final concept based on the sketches and make a particular use of the final creation easy. In this case, three designs in 3D have been made because of converting the sketches into 3D, from where the accurate assessment of each design was conducted to guarantee the most

accurate representation of each sketch design. The designs are carefully created with the aid of CATIA V5 software to portray the structural aspects, size and other characteristics of the jig.

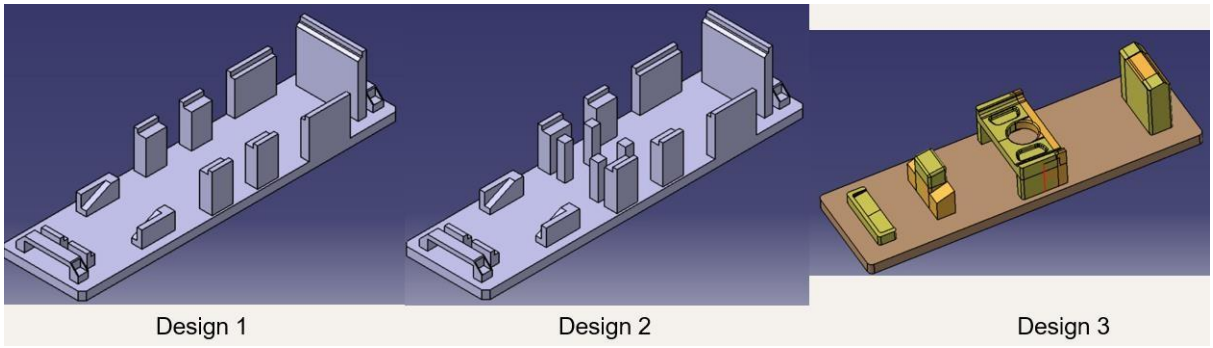

Figure 6: 3D design

2.4 Pugh matrix

In the Pugh Metrics design concepts are defined in the column while evaluation criteria are defined along the row. Each point of intersection in the matrix equals to the evaluation of how effectively one concept incorporates with another criterion [5]. To determine the optimal design option, the Pugh matrix is employed as an alternative method to the standard approach [6]. Table 1 below displays the first, second, and third designs identified using this Pugh Matrix. The matrix incorporates multiple criteria, including functionality, cost, quality, safety, and weight, and encompasses various concepts.

Table1: Criteria of the design

Criteria	Design 1	Design 2	Design 3
Functionality	+1	+1	+1
Cost	-1	-1	+1
Quality	+1	+1	+1
Safety	0	0	0
Total	2	2	3

Table 2: Legend of criteria

Legend	
-1	Not Good
0	Same
+1	Good

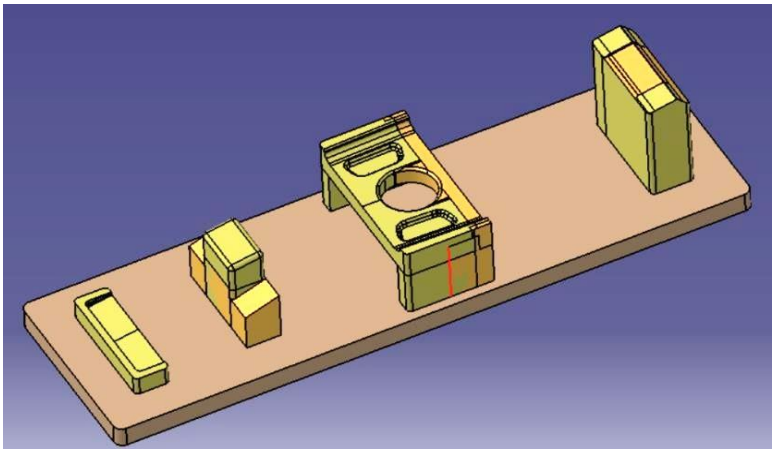

Figure 7: Final design

However, the primary virtue of simplicity of the Pugh metrics is that it is sufficient to contain several decision criteria, while providing far more flexibility compared to, for instance, the decision metrics [7]. The Jig console top garnish design chosen for workstation assembly line is jig design 3. This decision is based on the highest scores obtained through the Pugh Matrix used as a design selection criterion. Figure 11 illustrates a visual representation of the selected design created using Catia V5 software. Jig console top garnish 3 demonstrates superiority over the other two designs in terms of functionality, cost, and quality. Hence, Jig console top garnish 3 was selected as the final design.

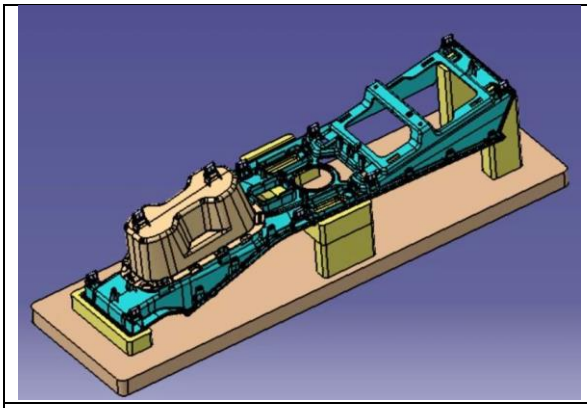

Figure 8: Assembly design

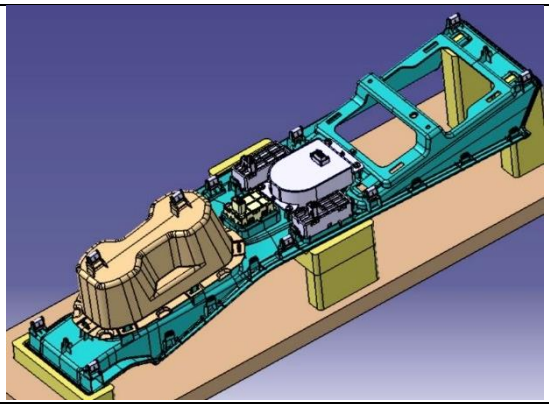

Figure 9: Assembly design

3.0 RESULTS AND DISCUSSION

The final design selected for the console top garnish jig to be used in the workstation assembly line is Jig Design 3. This selection was the result of a thorough design evaluation process, where three conceptual jig designs were developed and analyzed based on a set of critical performance criteria. To ensure an objective and systematic comparison, the Pugh Matrix method was employed as the primary design selection tool. This method allowed each concept to be evaluated against weighted factors such as functionality, ease of use, manufacturability, safety, cost, and ability to maintain part quality during assembly. Among the three options, Jig Design 3 achieved the highest overall score, demonstrating clear advantages in multiple areas over the other two alternatives.

Jig Design 3 was found to be the most effective in facilitating accurate part positioning, reducing operator handling time, and minimizing the risk of cosmetic defects such as scratches or misalignment. Additionally, it offered a more cost-effective solution by utilizing simpler components and requiring fewer manufacturing processes, without compromising structural integrity or functionality. In terms of quality assurance, Jig Design 3 provided the best support for ensuring consistency in the assembly process, which is critical in maintaining high standards for vehicle interior components.

Based on these strengths, Jig Design 3 was officially selected as the final design to be fabricated and implemented on the assembly line. Its adoption is expected to significantly improve assembly efficiency, reduce cycle time, and enhance the overall quality of the console top garnish installation process. This design serves as a practical and well-justified solution to the challenges previously faced in the manual assembly process, supporting the broader goal of continuous improvement in automotive manufacturing operations.

4.0 CONCLUSION

In conclusion, the successful design of a jig for the console top garnish panel assembly has been achieved through a structured engineering approach utilizing CATIA V5 software. The project began with the identification of challenges in the existing manual assembly process, such as prolonged cycle time, inconsistent alignment, and risk of surface damage. Through systematic analysis and concept generation, multiple jig designs were developed and evaluated using the Pugh method to ensure objective selection based on key performance criteria including functionality, quality, cost-effectiveness, and ease of use. Jig Design 3 emerged as the most suitable option, offering superior support in positioning the panel accurately and securely while minimizing the potential for defects. The use of CATIA V5 played a critical role in enabling precise 3D modeling, virtual validation, and design optimization before fabrication. The final design not only meets the functional and ergonomic requirements of the workstation but also contributes to improved assembly efficiency, reduced cycle time, and enhanced product quality.

ACKNOWLEDGEMENT

This study acknowledges the invaluable support and contributions of several individuals and organizations. Special thanks are extended to Azman Hamzah Plastik Sdn. Bhd. for granting access to their facilities and providing essential data that greatly supported the research. The guidance and insights from the development team were instrumental in identifying key areas in the design of the jig for the console top garnish panel assembly. In addition, sincere appreciation is given to the academic mentors from Politeknik Sultan Azlan Shah for their continuous support, encouragement, and expert guidance throughout the course of this project.

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Design of an Automated Conveyor System using Pugh Metrix Method

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ABSTRACT

This paper presents the design and evaluation of an automated conveyor system using the Pugh Matrix method; a systematic decision-making tool for concept selection. Conveyors are automated devices that move materials or products between operations, enhancing productivity and minimising the need for manual labour. The goal of this current project is to develop an efficient, cost-effective, and reliable conveyor system suitable for injection molding applications. Several design concepts were generated based on key criteria including part stability, ease of maintenance and cost of fabrication. The Pugh Matrix method was employed to compare and rank these alternatives against a baseline design by assigning weighted scores to each criterion. This structured approach enabled objective analysis and transparent justification for the final concept selection. The selected design was further developed using Computer Aided Design (CAD) Software. Results showed that the Conveyor Design 03 is the best design, outperforming both Design 01 and Design 02 in terms of overall performance, making it the preferred choice for continuation.

Keywords: conveyor system design, injection molding, Pugh Matrix, cleated belt conveyor, design evaluation

1.0 INTRODUCTION

Injection molding is widely used for manufacturing plastic parts due to its high repeatability, short production cycles, and ability to produce complex geometries with minimal waste (Gim & Turng, 2022). In industries such as automotive, this process is essential for interior components and structural plastic parts. Conveyors, particularly inclined belt conveyors with cleats, are commonly used in automated systems for part collection and transfer. Their role is vital in optimising workflows, reducing human effort, and increasing production throughput in industrial settings (Sakharwade & Nagpal, 2019). A critical issue in the injection molding process is the reliance on manual part retrieval from the injection molding machine producing Pull Cup Sport Front components. Manual handling increases cycle time, reduces daily output, and leads to overtime (Norzaimi et al., n.d.). This problem is worsened by rising production targets from 2120 to 2544 pieces per day (de Jesus Pacheco & Schougaard, 2024). Manual retrieval also introduces ergonomic risks (Hilmi et al., 2024) and inconsistent takt time, affecting quality and delivery. Therefore, the objective of this study is to design an automated conveyor system using the Push Matrix method.

2.0 METHODOLOGY

This project follows a structured product development methodology integrating the Pugh Matrix for design evaluation (Guler & Petrisor, 2021). The process includes identifying the problem, generating multiple conveyor design concepts, defining evaluation criteria, applying the Pugh Matrix for design selection, and selecting the best design for implementation. The

Pugh Matrix was chosen as the design evaluation method due to its effectiveness in eliminating weak concepts and supporting decision-making (Guler & Petrisor, 2021). This method has been successfully applied in various mechanical engineering applications to narrow down optimal designs.

2.1 Project Flowchart

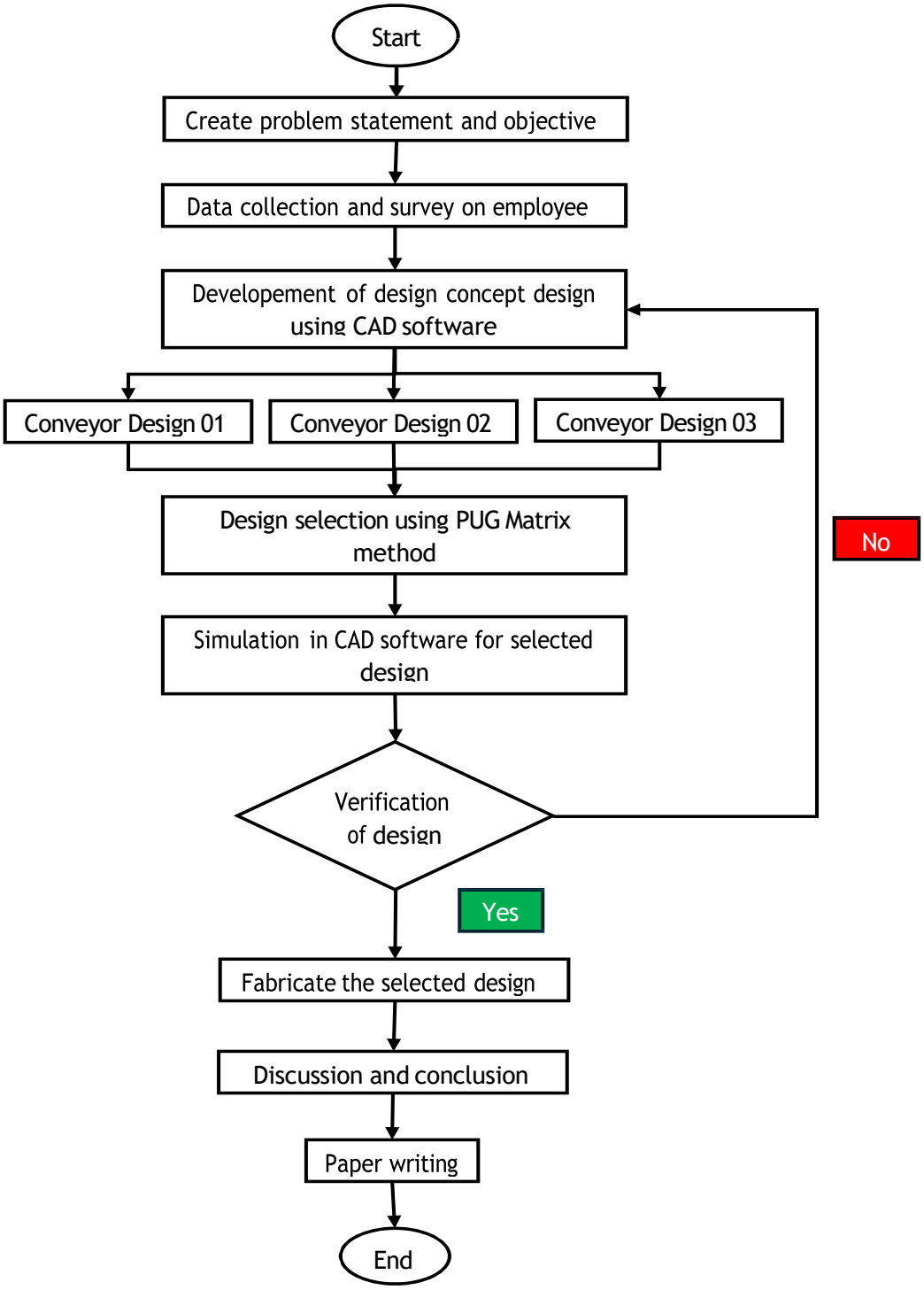


Figure 1: Project flowchart

Figure 1 project flowchart illustrates the comprehensive design process. The process begins by developing the problem statement and objectives, followed by collecting data and conducting employee surveys to identify actual issues. Geometric designs for various conveyor concepts are generated utilising Computer Aided Design (CAD) software. This includes three conceptual designs (Design 01, Design 02, and Design 03), subsequently assessed utilising the Pugh Matrix method. After the systematic assessment identifies the optimal design, CAD software is used to simulate the model and evaluate its practicality. If the design does not pass validation, it returns to the redesign phase. Once it meets the required criteria, the conveyor is fabricated. The project concluded with a discussion and conclusion based on the results, followed by the writing of the final report.

2.2 PUGH Matrix

Three key criteria were defined for evaluation. The first is part stability, which refers to the conveyor's ability to securely transport molded components without allowing them to slide, tip, or fall. This attribute is particularly important in inclined conveyors where gravitational pull can cause instability if not properly addressed. Cleats, guard rails, and the overall belt structure must be considered to ensure safe and stable transport of parts from the injection mold to the operator's table.

The second criterion is ease of maintenance, focusing on how accessible and user-friendly the conveyor is for routine services such as cleaning, troubleshooting, and replacing worn components. Conveyors in plastic molding environments are often exposed to dust, grease, and resin flakes; therefore, ease of maintenance is essential to ensure operational uptime and minimize disruptions.

The third criterion, cost of fabrication, considers the expenses associated with material procurement, labour for construction, and overall complexity of the design. A more complex system with intricate components may perform well but could be cost prohibitive, hence the need to strike a balance between functionality and economic feasibility. These three criteria collectively address the technical, operational, and economic aspects of conveyor system design, making them essential for evaluating which concept best fits the injection molding environment.

Table 1: The criteria of the design selection

Criteria	Explanation
Part stability	Ability of the design to prevent parts from slipping or falling during movement
Ease of maintenance	Accessibility and simplicity for routine cleaning, part replacement, and troubleshooting.
Cost of fabrication	Estimated cost to manufacture the conveyor, including materials, labor, and complexity.

Table 1 from Guler & Petrisor, (2021) above shows the design selection criteria, which present three critical elements for analysing and selecting effective designs. One of the most important requirements is part stability, which refers to the design's capacity to firmly retain components in place and prevent them from sliding or falling during use. This element is critical for guaranteeing consistent performance and reducing the likelihood of mechanical failure or product damage.

Another essential consideration is ease of maintenance, which refers to how accessible and simple the design is for common tasks like cleaning, changing parts, and troubleshooting. An easy-to-maintain design reduces operating downtime and promotes long-term efficiency.

The third criterion is the cost of fabrication, which includes the expected expenditures associated with creating the design. This includes raw material and labour costs, as well as the production process's complexity. A cost-effective design meets budgetary limits while simultaneously improving scalability for bigger production runs. Together, these criteria form a balanced framework for selecting a design that is stable, maintainable, and economically feasible.

Table 2: The scoring scale for the design selection

Score	Explanation
+3	Much better than reference
+2	Better than reference
+1	Slightly better than reference
0	Same as reference
-1	Slightly worse than reference
-2	Worse than reference
-3	Much worse than reference

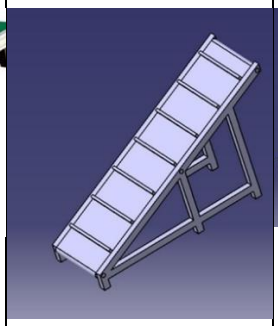
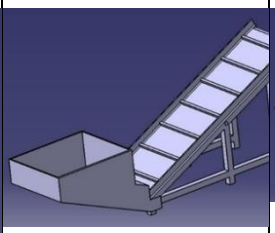
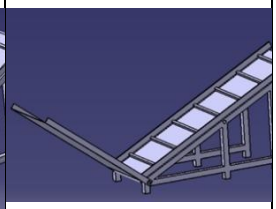
According to Table 2 above, the scoring method used in the evaluation matrix is meant to assess how different design options perform compared to a standard reference. A score of +3 means that the design is much better than the reference, showing major improvements in performance, efficiency, or usability. This usually suggests major advancement or very optimised feature. A score of +2 means that the design is better than the reference, showing clear benefits like more functionality or some cost savings, but it is not as impressive as the highest score. A score of +3 indicates that the design outperforms the reference, with significant improvements in performance, efficiency, or usability typically indicating a breakthrough or highly optimised feature. A +2 score indicates that the design outperforms the reference, indicating visible benefits such as greater functionality or moderate cost savings, but it is not as significant as the top score.

A score of +1 is given when the design is somewhat better than the reference, indicating tiny additions or marginal changes that provide value above the baseline. A 0 score indicates that the design performs the same as the reference, with no major differences in quality, performance, or cost. Negative ratings indicate shortcomings compared to the reference. A score of -1 indicates that the design is somewhat poorer than the reference, either owing to small inefficiencies or greater complexity. A -2 score indicates that the design is poorer than the reference, either owing to greater costs, inferior performance, or increased maintenance needs. Finally, a -3 indicates that the design is significantly worse than the reference, implying substantial flaws such as impracticality, high risk, or significant failure to satisfy specifications. This scale offers a formal and objective approach to evaluating design trade-offs and aiding decision-making in engineering analysis.

3.0 RESULTS AND DISCUSSION

Table 3 presents a comparative analysis of three conveyor design alternatives versus a design reference utilising a Pugh matrix, evaluated based on three criteria: part stability, ease of maintenance, and cost of fabrication.

Table 3: Pugh Matrix design selection

Criteria	Design reference	 Conveyor Design 01	 Conveyor Design 02	 Conveyor Design 01
Part stability	0	+1	+3	+3
Ease of Maintenance	0	0	-2	-1
Cost of fabrication	0	-1	-2	-1
Score	-	0	-1	+1
Rank	-	3	2	1
Continue	NO	NO	NO	YES

Part stability is an important consideration in conveyor system design because it ensures precise placement and safe conveyance of goods while in operation. In the Pugh Matrix review, both Conveyor Design 02 and the alternative Conveyor Design 01 obtained the highest possible score of +3, signifying a 300% performance gain over the baseline reference design that scored 0. This improvement is most likely due to their inclined designs and incorporated containment features, which assist in minimising slippage and misalignment of pieces during movement. In comparison, Conveyor Design 01 achieved a moderate score of +1, reflecting a 100% improvement in stability. However, it lacked the advanced part-guiding mechanisms present in the highest-performing designs.

Stability during travel is critical for reducing jamming and increasing overall process accuracy. According to Feng et al., (2020), the dynamic properties of belt conveyors under non-uniform loads have a substantial impact on their operational stability, emphasising the need for optimal design when ensuring continuous material flow. Djuraev et al. (2023) also investigated the dynamics of belt conveyors with composite guide rollers and elastic components, indicating that such designs may efficiently mitigate vibrations and improve the stability of transported products (Djuraev et al., 2023). Additionally, Krol et al. (2021) studied how well steep belt conveyors work and found that using belts with bumps and the right angles can greatly improve the stability of the materials being moved, especially in tough areas. As a result, the higher- rated designs in the matrix are more suitable for applications that need consistent and steady

transportation, such as precision packing, inspection, or robotic assembly (Hrabovský & Fries, 2021).

Ease of maintenance is critical for reducing downtime and increasing conveyor system operating life. In the Pugh Matrix examination, both the reference design and Conveyor Design 01 obtained neutral ratings of zero, suggesting no difference in maintainability. Conveyor Design 02 and the alternative Conveyor Design 01 were scored -2 and -1, respectively, reflecting a 200% and 100% decrease in ease of maintenance compared to the standard. These lower ratings indicate that, despite possible gains in some stability, the more complicated structures of these designs may impede access to important components, lengthen disassembly time, and raise maintenance requirements.

Recent advances in smart manufacturing technology provide solutions to these maintenance difficulties. Pulcini and Modoni (2024) created a machine learning-based digital twin for conveyor belts, allowing for real-time defect prediction through sensor data analysis. Their research proved excellent precision and accuracy in recognising problem states within acceptable time constraints, hence avoiding unexpected downtime (Pulcini & Modoni, 2024). Similarly, Mahmood and Shareef (2024) performed a thorough investigation of the use of artificial intelligence in smart conveyor belt monitoring systems. They emphasised that using AI technologies, such as machine learning algorithms and computer vision systems, improves fault detection accuracy while reducing system maintenance time by at least 30%. These findings show that even though complex conveyor systems can have typical maintenance problems, their performance can be kept the same or even better with the use of modern predictive and preventive maintenance methods (Mahmood & Shareef, 2024).

Fabrication cost is an important consideration in conveyor system design since it has a direct influence on manufacturing feasibility and scalability. In the Pugh Matrix examination, the reference design received a score of 0. Conveyor Design 01 achieved a +2 score, signifying a 200% increase in fabrication cost efficiency compared to the reference. Conveyor Design 02 and the alternative Conveyor Design 01 were scored -1 and -2, respectively, indicating a 100% and 200% increase in fabrication costs above the baseline. These variances highlight the relevance of design decisions in determining production costs.

Recent research has shown that using Design for Manufacturing and Assembly (DFMA) principles may drastically cut fabrication costs in conveyor systems. For example, Butt and Javed (2020) conducted a full redesign of an existing conveyor system, resulting in a 29% reduction in manufacturing costs and a 57% reduction in assembly time (Butt & Jedi, 2020). Their methodology included streamlining the conveyor structure, lowering part numbers, and optimising assembly operations. Similarly, Boslovyak & Lagerev, (2019) developed an algorithm for the optimal design of a suspended belt conveyor's metal structure, achieving material savings and cost reductions by minimising the mass of the conveyor components. These findings highlight the effectiveness of strategic design modifications in enhancing cost efficiency.

4.0 CONCLUSION

According to the comparison study utilising the Pugh Matrix, Conveyor Design 03 is the most optimum design, with a total score of +1, compared to 0 for Conveyor Design 01 and -1 for Conveyor Design 2. This score demonstrates its excellent performance, especially in part stability, where it receives a +3 rating, representing a 300% improvement over the baseline

design reference. Design 01 achieves a modest +1 (100% improvement), whereas Design 02, despite matching the +3 stability score, suffers from -2 ratings in maintenance and fabrication cost, leading to the lowest total score.

While Conveyor Design 03 presents minor drawbacks, with scores of -1 in both ease of maintenance and fabrication cost, these are relatively insignificant compared to the more severe penalties of Design 02, which scored -2 in both categories. Design 01, on the other hand, offers no improvement over the reference in ease of maintenance and introduces a financial penalty without delivering a notable performance gain. Despite its modest trade-offs, Design 03 emerges as the most well-rounded and performance-effective solution.

Furthermore, Design 03's balanced approach makes it the most promising choice for future evolution. Its already favourable score may be improved further by making design changes, such as optimising maintenance access points or choosing different materials to lower fabrication costs. In conclusion, Conveyor Design 03 is the best final design, exceeding both Design 01 and Design 02 in terms of overall performance, making it the preferred choice for continuation.

ACKNOWLEDGEMENT

This study gratefully acknowledges the invaluable support and contributions of various individuals and organizations. Special appreciation is extended to ABC Company for granting access to their facilities and providing critical data essential to this research. The expertise and guidance of the engineering team played a pivotal role in identifying key areas for improvement in the injection molding process. Sincere thanks are also due to the academic supervisor from Politeknik Sultan Azlan Shah for their unwavering support, insightful feedback, and expert guidance throughout the duration of this project.

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Design of Shaft Gear Lubrication Jig in Power Window Assembly

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ABSTRACT

This study addresses high cycle time in the lubrication process of the power window regulator assembly. The objective is to design a lubrication jig that reduces cycle time and improves process efficiency at workstation P3. The study employed observational methods and time-motion analysis to identify inefficiencies in the greasing process. A lubrication jig was then designed using CAD software and evaluated using a Pugh Matrix to select the most effective design. The selected jig (Design A) significantly improved operator ergonomics and reduced the greasing time by 50%, from 6 seconds to 3 seconds. The Pugh Matrix confirmed Design C as the best option based on criteria such as cycle time reduction, ergonomics, cost-effectiveness, and durability. Following implementation, the jig enhanced workflow continuity and minimized manual effort.

Keywords: cycle time, lubrication jig, time-motion study, ergonomic design, power window assembly.

1.0 INTRODUCTION

In the highly competitive automotive industry, operational efficiency is crucial for maintaining a company's competitiveness and meeting the increasing demands of consumers. Cycle time (CT), which refers to the total time required to produce a single unit, is a key metric used to assess manufacturing efficiency. Reducing cycle time not only increases productivity but also lowers production costs, enhances throughput, and enables manufacturers to meet customer delivery expectations more effectively (Vijayakumar & Suresh, 2022)

Company A specializes in the production of high-quality automotive components, including door mirrors, door handles, and power window regulators. While the company has made consistent efforts to optimize its production processes, it continues to face significant challenges in reducing cycle time particularly in the assembly of power window regulators. One of the most critical bottlenecks lies in the lubrication stage, which relies heavily on manual intervention and repetitive motion. This not only increases the cycle time but also impedes the overall efficiency of the assembly line.

Figure 1 shows the cycle time and target cycle time for every workstation. The lubrication process at workstation P3 has been identified as a major bottleneck in the production line. Specifically, the cycle time for this process often exceeds the target time, leading to delays that impact subsequent workstations and reduce overall production output. At workstation P3, which involves greasing the shaft gear, the process exceeds the target cycle time of 15 seconds, with current operations taking up to 18 seconds. This time discrepancy not only slows down the entire assembly line but also disrupts the flow of subsequent operations, leading to inefficiencies and difficulty in meeting production targets.

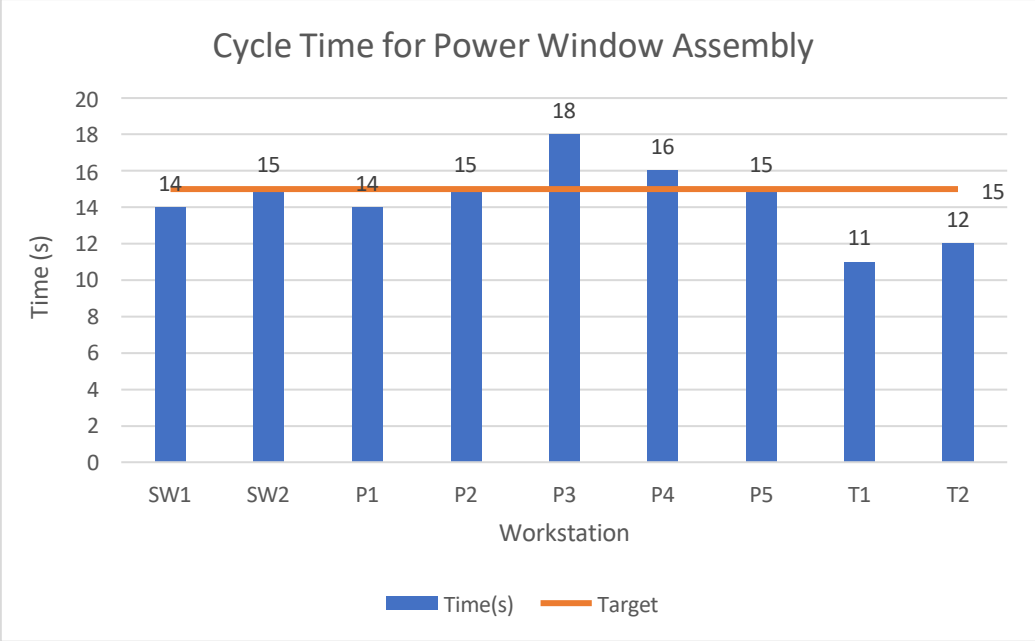

Figure 1: Cycle Time for Every Workstation in Power Window Assembly.

The aim of this study is to improve the efficiency of the lubrication process in the power window regulator assembly by using lubrication jig. By addressing the inefficiencies in this process, the study seeks to reduce cycle time, eliminate non-value-added activities, and help the company achieve its target cycle time of 15 seconds. This research will utilize qualitative observational methods and lean manufacturing principles to provide practical solutions for optimizing the lubrication process and improving overall productivity. The findings from this study will not only support Delloyd Industries in achieving its production goals but will also provide valuable insights that can be applied to similar manufacturing challenges in the automotive industry.

2.0 BACKGROUND STUDY

This study is grounded in the principles of lean manufacturing, which originated from the Toyota Production System and emphasizes the elimination of waste, enhancement of process efficiency, and maximization of value-added activities(N. Kumar et al., 2022). Core lean concepts such as Just-In-Time (JIT), continuous improvement (Kaizen), and value stream mapping serve as foundational strategies for reducing variation and increasing productivity in manufacturing operations. Within this context, the use of jigs plays a critical role in achieving precision, consistency, and repeatability in repetitive production tasks(S. Kumar et al., 2019). Various types of jigs including drilling, boring, reaming, milling, template, plate, and channel jigs are instrumental in improving accuracy, minimizing human error, and simplifying

complex operations. Their implementation is especially beneficial in high-volume industries like automotive assembly, where they contribute to reduced cycle time and enhanced operator ergonomics.

Another key focus is the management of cycle time (CT), which encompasses the total time taken to complete a process, including both value-added and non-value-added activities. Tools such as time-motion studies and value stream mapping are essential in identifying inefficiencies and production bottlenecks(Vijayakumar & Suresh, 2022). Effective CT management leads to faster production lead times, reduced costs, and greater customer satisfaction. The review also addresses the "7 Wastes" defined in lean manufacturing—overproduction, waiting, transportation, overprocessing, inventory, motion, and defects—along with the eighth recognized waste: underutilization of human talent. Eliminating these wastes is crucial for improving workflow and overall production efficiency(Aucasime-Gonzales et al., 2020).

Despite extensive research in lean manufacturing and general process optimization, there remains a notable gap in the application of jigs for lubrication tasks within automotive assembly. Current literature lacks targeted studies addressing the manual inefficiencies involved in lubrication processes. This identified gap underscores the significance of the present study, which aims to develop and evaluate jig-based solutions to improve cycle time and operational efficiency in lubrication-related tasks.

3.0 METHODOLOGY

This section outlines the systematic approach undertaken to achieve the objectives of this study, focusing on improving the lubrication process in the power window assembly line.

3.1 Observation

The Observation Method was employed as the primary qualitative approach to collect real-time data on the Power Window assembly line, with a specific focus on Workstation P3 (Alam, 2021). This method involves systematically observing and recording operator actions and task execution during actual production to gain a deeper understanding of workflow efficiency and identify areas for improvement. At Workstation P3, the operator is responsible for installing short brackets, applying grease to the brackets and shafts, and inserting the components into the stopper machine. This station was identified as a significant source of inefficiency due to its prolonged cycle time, which greatly exceeds the targeted 15 seconds. The primary issue observed was the motion-intensive task of greasing both sides of the shaft gear, which contributes to excessive delays and increased physical exertion. Through direct observation, these inefficiencies were clearly identified, laying the groundwork for targeted improvements to streamline operations and enhance productivity at this critical workstation.

3.2 Time and Motion Study

The data collection for this study specifically focused on the P3 workstation of the power window assembly process, employing a detailed Time and Motion Study approach. A combination of digital stopwatch timing and video analysis was used to accurately capture the cycle time data associated with each task at P3(Sotsek et al., 2022). Each task performed at this workstation was timed manually using a stopwatch, with five repetitions per task to obtain a reliable average cycle time. This data collection was conducted consistently over a one-month period, ensuring that the results reflected typical working conditions at P3.

Table 1: Standardize Check Sheet

Workstation/ Task	1	2	3	4	5	6
P3						
Average Time(s)						

To systematically record the observed times, a standardized check sheet was utilized. In parallel, video recordings were made to validate the manual timings. These videos enabled the researcher to review each activity multiple times, minimizing human error and allowing for the identification of subtle inefficiencies that may not have been visible during live observation.

The dual-tool method provided a high level of measurement accuracy, offering deeper insights into operator movements, task sequences, and micro-delays that contribute to bottlenecks at P3. This focused analysis of the P3 workstation allowed for a comprehensive understanding of its performance and highlighted key opportunities for process improvement and cycle time reduction.

3.3 Pugh Matrix Evaluation

To evaluate the proposed jig designs objectively, the Pugh Matrix was used as a structured decision-making tool. This method allowed for a systematic comparison of each design alternative against key performance criteria relevant to the shaft gear lubrication process in the power window regulator assembly. Each design was scored on a scale of 1 (Poor), 2 (Moderate), and 3 (Excellent), with weighted percentages applied to reflect the relative importance of each criterion (Guler & Petrisor, 2021).

The evaluation focused on five critical factors: cycle time reduction (25%), ease of operation (20%), cost (15%), ergonomics (20%), and reliability (20%). These criteria were selected to ensure that the final design would support both operational efficiency and practical usability within the production line (Joshi, 2019). Based on the total weighted scores, Design C emerged as the most favorable option, achieving the highest score of 2.85. While its cost score was moderate, its superior performance in reducing cycle time, improving ergonomics, and ensuring high reliability made it the optimal choice for implementation.

3.4 CAD Design Detailing

The jig design was meticulously developed using CAD software, a robust Computer-Aided Design tool widely adopted in engineering and manufacturing. The design process adhered to a structured methodology to ensure precision, functionality, and manufacturability suitable for the power window regulator assembly process.

3.5 Testing and Analysis

After jig development, it will be tested for implementation at the workstation. Data collection methods will be used to gather information on cycle times and operator movements. The data collection will be conducted over a duration equivalent to five times the cycle time of the riveting process. The collected data will be thoroughly analyzed using time study methods to identify bottlenecks. The analysis will be carried out using Excel to generate graphs and observe trends in the data.

4.0 RESULTS AND DISCUSSION

4.1 Time and Motion Analysis

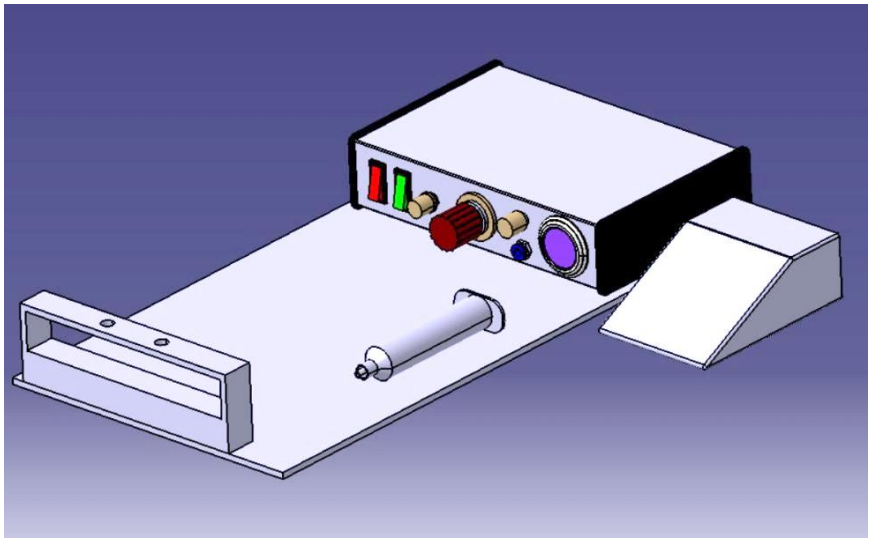

Figure 2: Design A

Figure 2 shows the proposed jig design, which includes a 50 ml syringe, foot switch, and a dual-nozzle grease dispenser. However, it requires repetitive motion to grease both sides of the shaft gear, and the small syringe capacity leads to frequent refills, interrupting workflow and increasing cycle time.

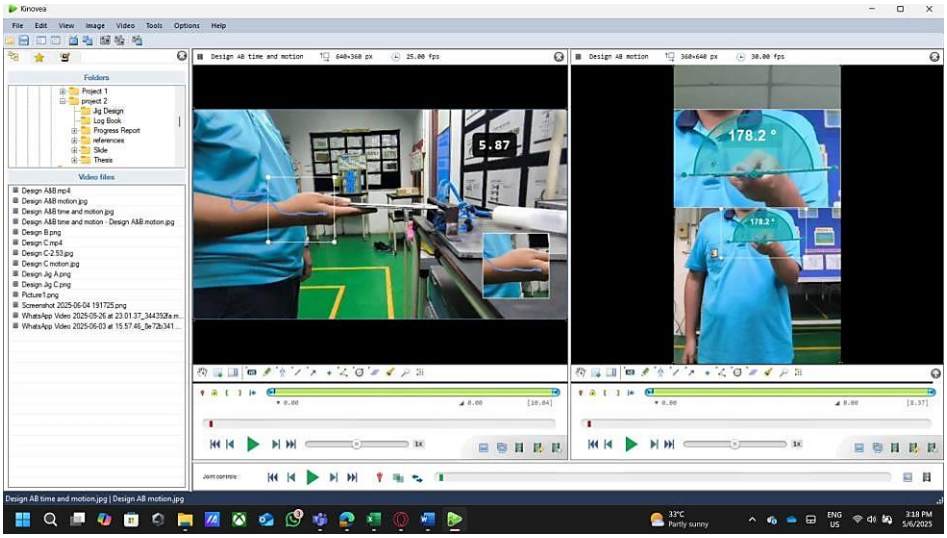

Figure 3: Movement Analysis Design A

Figure 3 shows the analysis of Design A using Kinovea software. The 180-degree wrist rotation required during greasing causes the cycle to take 6 seconds to complete.

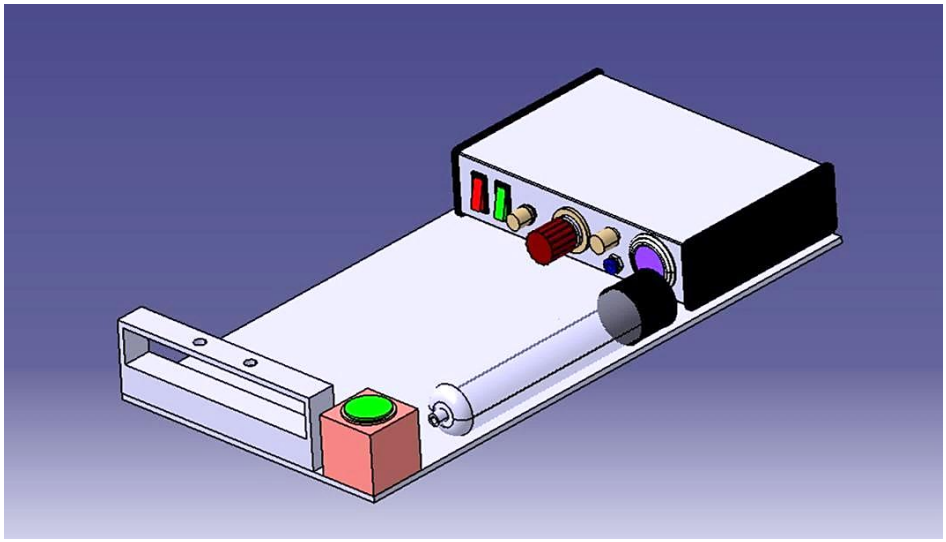

Figure 4: Design B

Figure 4 illustrates Design B, the second proposed design. Unlike Design A, it uses a larger 200 ml syringe to reduce refilling frequency, improving workflow and productivity. Although it retains the same grease dispenser, the foot switch is replaced with a hand-operated switch, requiring the operator to use both hands one for holding the shaft gear and the other for activating the switch. This increases operator's workload and may reduce precision. Similar to Design A, it still involves repetitive movements to grease both sides of the shaft gear, potentially causing fatigue and reducing efficiency.

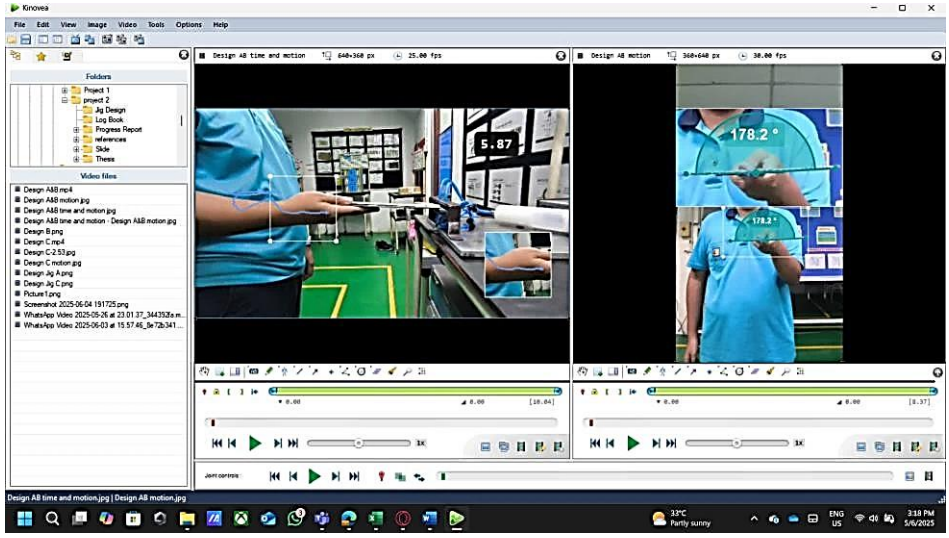

Figure 5: Design B Movement Analysis.

Figure 5 presents the Kinovea software analysis of Design B, showing that the 180-degree wrist rotation during the greasing process results in a cycle time of 6 seconds.

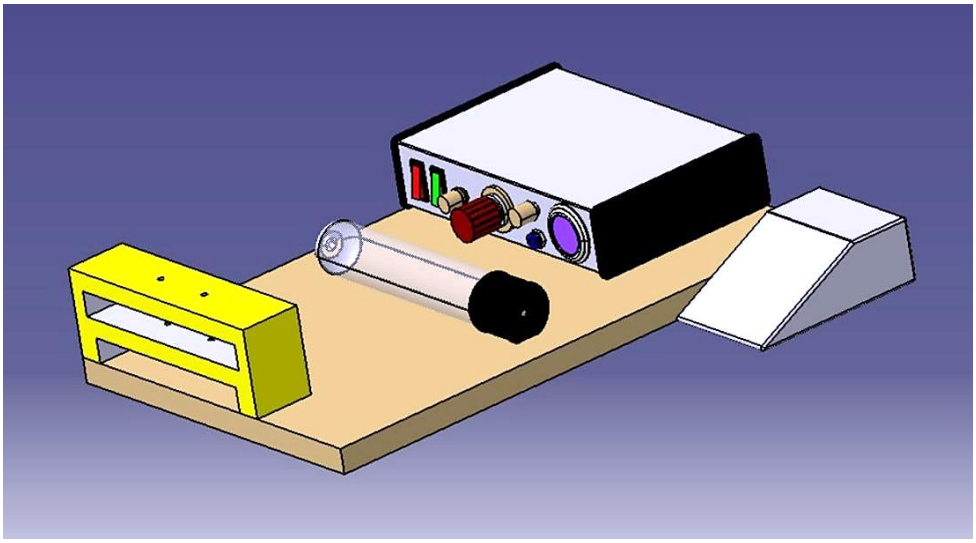

Figure 6: Design C

Figure 6 illustrates Design C, the third proposed option. Like Design B, it employs a 200 ml syringe to reduce refill frequency, minimizing downtime and improving workflow. A foot switch enables hands-free operation, decreasing hand strain and allowing the operator to concentrate on positioning. The grease dispenser has two outlets—one at the top and one at the bottom—so both sides of the shaft gear can be greased simultaneously. This eliminates repetitive movements and enhances productivity and ergonomic efficiency.

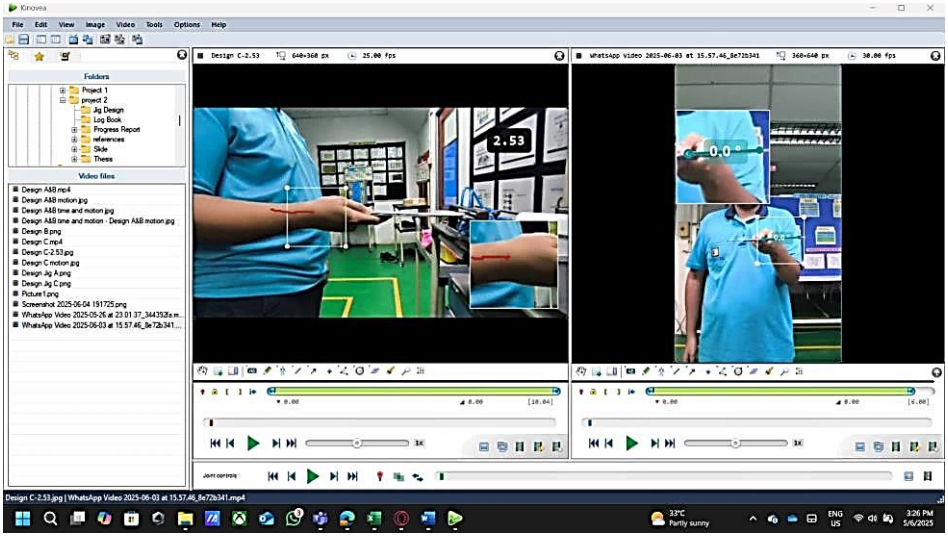

Figure 7: Movement Analysis of Design C

Figure 7 presents the Kinovea software analysis of Design C, indicating that the absence of wrist rotation during the greasing process reduces the cycle time to 3 seconds.

4.2 Cost Analysis

Table 2: Component Cost Analysis

Components	Design A	Design B	Design C
Base	Material: Aluminum Plate Size:200mm x 200mm x 10mm Price: RM 75	Material: Aluminum Plate Size:200mm x 200mm x 10mm Price: RM 75	Material: Mild Steel Plate Size: 200mm x 200mm x 10mm Price: RM 30
Grease Dispenser	Material: Mild Steel Price: 27.60	Material: Mild Steel Price: 27.60	Material: Mild Steel Price: 27.60
Pneumatic Dispenser	RM 367.50	RM 367.50	RM 367.50
Grease Tank	Type: Syringe 50 ml Price: RM 3.60	Type: Syringe 200 ml Price: RM 23	Type: Syringe 200 ml Price: RM 23
PU Tube	Size: 6mm x 4mm x 1000mm Price: RM 2	Size: 6mm x 4mm x 1000mm Price: RM 2	Size: 6mm x 4mm x 2000mm Price: RM 4
Total Cost	RM 475.70	RM 488.10	452.10

4.3 Chosen Design Concept

After analyzing the design alternatives, the Pugh method was applied to select the most suitable design by objectively evaluating and comparing each option based on five weighted criteria: cycle time reduction (25%), ease of operation (20%), cost (15%), ergonomics (20%), and reliability (20%).

Table 3: Pugh Matrix Score

1	Poor
2	Moderate
3	Excellent

Table 4: Pugh Matrix Evaluation

Criteria	Weight (%)	Design A (Score × Weight)	Design B (Score × Weight)	Design C (Score × Weight)
Cycle Time Reduction	25% (0.25)	2 × 0.25 = 0.50	2 × 0.25 = 0.50	3 × 0.25 = 0.75
Ease of Operation	20% (0.20)	3 × 0.20 = 0.60	2 × 0.20 = 0.40	3 × 0.20 = 0.60
Cost	15% (0.15)	2 × 0.15 = 0.30	1 × 0.15 = 0.15	3 × 0.15 = 0.45
Ergonomics	20% (0.20)	2 × 0.20 = 0.40	1 × 0.20 = 0.20	3 × 0.20 = 0.60
Reliability	20% (0.20)	2 × 0.20 = 0.40	2 × 0.20 = 0.40	3 × 0.20 = 0.60
Total Score	100%	2.2	1.65	3

Based on Table 3, Design C was selected as the most suitable option among the three alternatives. The evaluation considered five weighted criteria: Cycle Time Reduction (25%), Ease of Operation (20%), Cost (15%), Ergonomics (20%), and Reliability (20%). Design C achieved the highest total weighted score of 3.00, compared to Design A (2.20) and Design B (1.65).

Design C outperformed the other designs in critical areas such as cycle time reduction, ergonomics, and reliability, highlighting its potential to enhance productivity, operator comfort, and process consistency. Although its cost is slightly higher than the others, the overall performance benefits outweigh this drawback. Therefore, Design C is recommended for implementation due to its superior and well-balanced performance across all key evaluation criteria.

4.4 Data Collection of Sample Before and After Jig Implementation

Table 5: Data Collection Before and After Jig Implementation

Sample No.	Before (sec)	After (sec)
1	6.2	3.1
2	5.8	2.9
3	6.3	2.8
4	5.9	3
5	6.1	3.2
6	5.7	2.7
7	6	3.3
8	6.4	3.1
9	5.9	2.9
10	6.2	2.8

Table 4 shows the data collected before and after the implementation of the jig. The data was gathered through testing the jig on the power window line assembly.

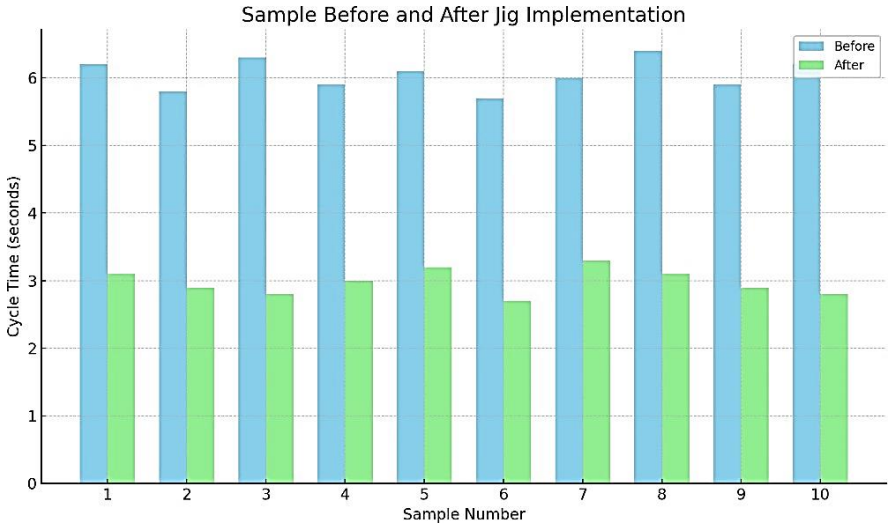

Figure 8: Cycle Time Sample Before and After Jig Implementation.

Figure 8 illustrates the comparison of cycle times for each sample before and after jig implementation in the power window line assembly. The data shows a consistent reduction in cycle time across all samples, with average times decreasing from approximately 6 seconds before the jig to around 3 seconds after its implementation.

4.5 After Jig Implementation

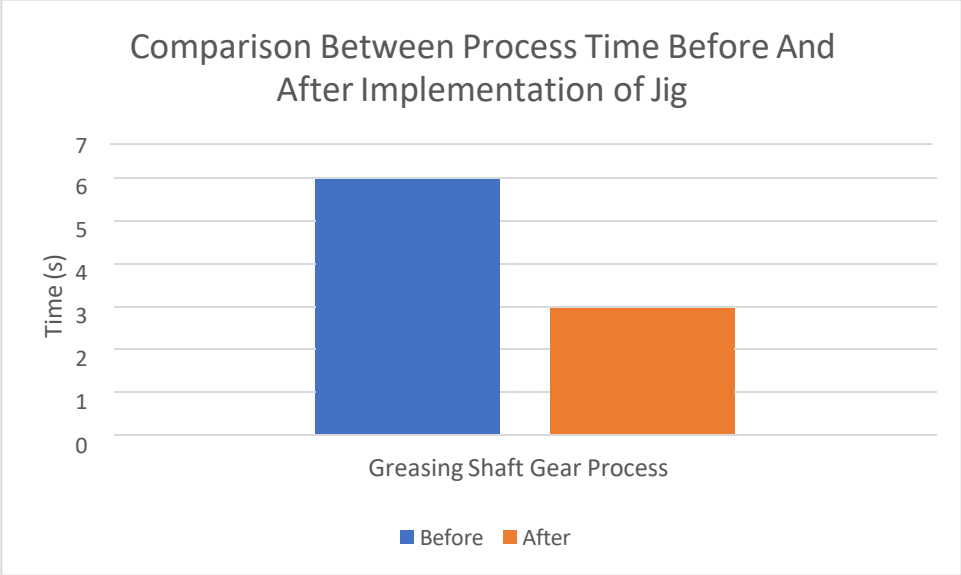

Figure 9: Comparison Between Process Time Before and After Implementation

Figure 9 presents a comparison of process times before and after the implementation of the jig. The introduction of the jig has significantly improved the efficiency of the greasing process for the shaft gear. Specifically, the time required for this task was reduced from 6 seconds to 3 seconds, representing a 50% decrease in cycle time.

5.0 CONCLUSION

This study successfully designed and developed a lubrication jig to improve the efficiency of the lubrication process in the power window regulator assembly at Delloyd Industries. Following implementation, the greasing process time at the P3 workstation was reduced by 50%, decreasing from 6 seconds to 3 seconds.

The results demonstrate that the lubrication jig effectively reduces cycle time and enhances assembly line productivity. This confirms that targeted tooling solutions can lead to significant improvements in manufacturing efficiency.

Future research should explore automation or sensor integration to further optimize cycle time. Additionally, applying similar design improvements to other assembly processes and workstations may yield further productivity gains.

ACKNOWLEDGEMENT
I would like to express my sincere gratitude to Company A. for their support and cooperation throughout this study. Special thanks to my mentor, En. Husnil Amar Bin Mohd Hanizam, for his invaluable guidance and expertise, as well as to my polytechnic lecturer, En. Baharuddin Bin Mohd Zanggi, for his continuous encouragement and constructive feedback. I also appreciate the assistance of the production staff, whose insights and collaboration in data collection were crucial to the success of this study. Their dedication and commitment to process improvement have greatly contributed to this study.

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Development of a Jig for Rear Engine Mounting Assembly to Reduce Cycle Time in EV Production

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ABSTRACT

The objective of this study is to ensure both precision and consistency in the final phase of production and to design a special jig for the rear engine mounting assembly at company A, considering the widespread demand for electric vehicle (EV) parts. The purpose is to ensure accurate assembly, less variation in the manufacturing process and maintain product quality by making and using a jig that fits the press machine. The team used CATIA V5 for design, then made a prototype, looked at customers' concerns and used a Fishbone analysis which helped identify what affected the quality of the product the most. The study revealed assembly became faster, there were fewer defects, and the process was more dependable. The study advises that the jig should be put into full-scale operation to keep up with the progress in efficiency and quality of EV part assemblies.

Keywords: Jig design, assembly efficiency, electric vehicle, process improvement, quality control

1.0 INTRODUCTION

The higher demand for equipment for electric cars, suppliers have to improve how they assemble and quality-check their parts. There are problems with consistency and quality at Company A when assembling the parts of the rear engine mounting. Proper assembly-press machines use jig to help ensure the parts are produced accurately, consistently and on schedule. The project aims to fix Company A's problem by making a dedicated jig to hold the rear engine with CATIA V5 software. By studying the jig, the aim is to see if it helps the assembly line run more efficiently to lower the number of defects and lead to careful component placement. It will see Company A meet the increasing interest in top-quality equipment for electric vehicles. It's an important field since it raises the productivity of assembly, makes processes consistent and increases the quality of products. The project supports lean manufacturing in the automotive components sector since it designs this jig.

1.1 Problem Statement

The high demand for electric vehicles has put more pressure on Company A, now Company A must work harder to manufacture them without lowering quality. There is not a jig for a press machine necessary to assemble rear engine mountings which explains why assembly takes so long, costs more and is not very productive. This addresses issues with product quality and whether the company meets what customers want. If there is no jig, someone must manually adjust the parts many times and since this job is not easy or uniform, it will be both costly and inefficient.

These pictures, Figures 1, show that the rear engine mounting assembly at Company A is installed by hand without a specific alignment jig. Due to this, human failures, irregularity and time constraints lead to mistakes and the discarding of completed work. A lack of a standard jig means errors and inconsistency which leads to bad performance, more wasted products, unhappy customers and loss of profit.

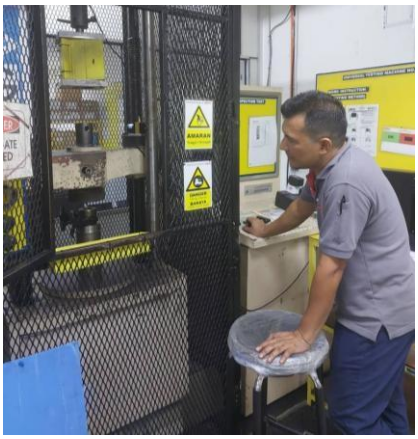

Figure 1: Manual process

Figure 2: Assembly process without proper jig

1.2 Objectives

i. To measure the effectiveness of the jig in improving the cycle time.

1.3 Literature Review

1.3.1 Poka-yoke

Poka-yoke techniques help to increase the efficiency of manufacturing process due to elimination of human errors and defects and results in product quality improvement (Tomar et al., 2007). These are the error-proofing techniques that guarantee uniform results and reduce the operational inefficiency. If poka-yoke devices are introduced into the assembly lines then the process can be standardized and mistakes are eliminated, which increase efficiency and quality. These systems also act to eliminate the bottlenecks, because the errors do not reach the flow of production, thus allowing smooth operations. Poka-yoke is required in Six Sigma since using the same, rework is minimized, and high-quality levels are assured. Also, it increases training, elevates workflow and expedites issue resolution leads to more throughput and overall optimization (Saurin et al., 2012).

1.3.2 Pugh Matrix

Using the Pugh Matrix, you can make decisions on alternatives for a design by considering factors like cost and robustness, so, difficult decisions in manufacturing are eased. This method aids small design teams in experimenting with new ideas until they get the right solution and it brings all stakeholders closer to understanding the project when conditions are complicated. Pugh Matrix makes decision-making easier by allowing comparison of various options in the conceptual phase for creating jigs (Olabanji & Mpofu, 2020). Using fuzzy logic allows it to deal with judgmental considerations and because of this, it can respond to demands by the market and functions. It mostly allows design choices that are informed by details and purpose.

2.0 METHODOLOGY

Company A is organized by this chapter to develop a custom jig to install their engine in the rear position. While conducting methodology, engineers and operators are supported as they deal with problems related to assembly during work in the industry. Methods based on observing, holding brainstorming sessions, using CATIA V5 design, using Fishbone Analysis and evaluating metrics are used to look for issues in the product design and to evaluate it. Following lean guidelines to reduce waste and with improved workflows, a prototype and tests are done to check the jig and sturdy materials are picked. Quantifying its effect is facilitated by the Pugh Matrix, to help cut down on defects, the time processes take, and any comments given by users. This study uses the Plan-Do-Check-Act (PDCA) cycle (as illustrated in Figure 3) to plan and execute each phase of research.

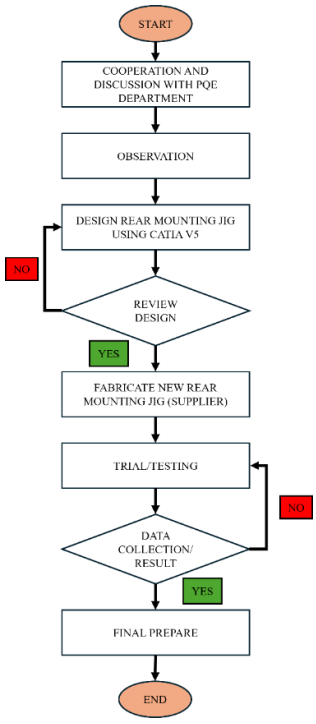

Figure 2: Flow Chart

2.1 Cooperation and Discussion

The jig development for rear mounting has a collaborative approach like Toyota Way and consists of engineers, operators, and quality teams. Such groupwork leads to feasible, workable designs, based on production requirements. Working together with the PQE department serves to underscore the power of cross-functional contributions to the refining of the jig, and its validity reflecting Toyota's commitment towards collaborative endeavours and continuous improvement. Knowledge sharing took place in terms of evaluating the best assembly techniques, resolving issues such as manual press and technical demands including dimensions, tolerances, and material specifications. Crucial queries defined the design- addressed output objectives, automation requirements, flexibility, as well as safety to re-assure that the jig addressed the assembly line requirements properly.

2.2 Ishikawa Diagram (Fishbone Diagram)

Researchers gathered the key findings and summarized them into broad categories found in the Ishikawa fishbone diagram which highlighted the main reasons for the failures. Because of the visualization, the jig design could target the most significant issues in the factory. As shown in Figure 3, there are these main factors.

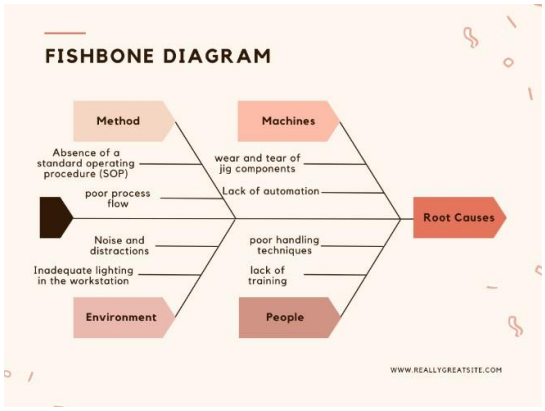

Figure 3: Ishikawa Diagram

2.2.1 Method:

A lack of standard operating procedure (SOP) creates various practices and product variability. Sequencing of task and order lack as well reduce productivity of employees.

2.2.2 Machines:

Poor quality materials and the absence of maintenance results in component wear, jig failure and downtime. The manual operations that are not automated add up to the errors and inefficiencies.

2.2.3 Environment:

Bad lighting impacts on precision and defect recognition, whereas noisy or chaotic environments divert operators and diminish attention and performance.

2.2.4 People:

Failure to give proper training and give clear guidelines on using the jig causes manipulation of the jig, part misplacement and incorrect force application errors, damages and interruptions of the process.

2.3 Concept and Design

Some of the vital criterions that were considered while selecting the most ideal designs for the rear mounting jig within this thesis include functionality, product manufacturability, cost – effectiveness and user-friendliness. Three conceptual designs were compared with the respect to trade-offs to improve the assembly line's efficiency, accuracy, and safety towards operators. The capability of each design to hold components securely, adjustability, and ability to enhance the effect of productivity on the overall system were all studied. After in-depth comparison, the three top designs were picked for more development and evaluation. The above selected concepts are shown in Figure 4, Figure 5 and Figure 6.

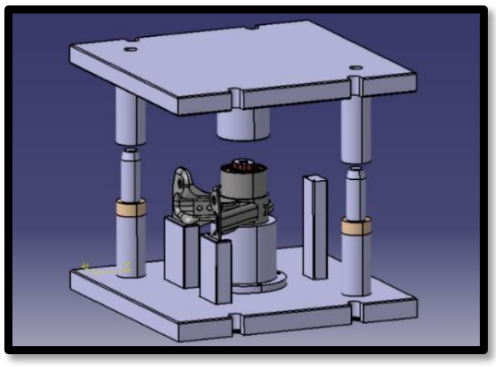

Figure 4: Concept Design A

Out of all these designs, Design A is easy to use, precise and safe for positioning. It is meant to provide a safe and comfy workspace for operators so that their work is always efficient and quick. The qualifications were all greatly achieved. The final decision was taken to select this design.

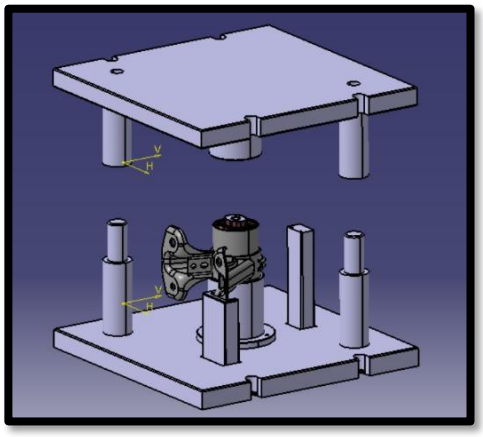

Figure 5: Concept Design B

With Design B, you get fewer resources and fewer safety and positioning features. Possible problems could happen if controlling the machine only by hand. Its levels of efficiency and safety are generally very low. It is not the best tool for mass production.

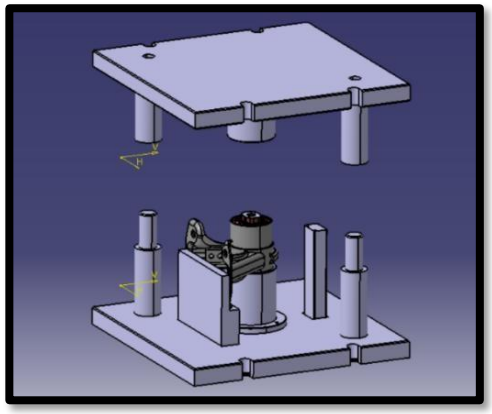

Figure 6: Concept Design C

Both the expenses and the performance stay optimal in Design C. The profile includes average security, alignment and flexibility. It is more affordable than Design B, but it is less practical than Design A. Pick it if you wish to save funds but explore other ones for greater optimization.

2.4 Pugh Matrix

In a systematic manner of design evaluations comparison, the new rear engine mounting jig's design alternatives were evaluated and compared using the Pugh Matrix. In considering options in comparison with such criteria, as robustness, cost, efficiency, and simplicity of implementation, it guaranteed an objective and structured selection process. Iterative adjustments to weights of criteria assisted to align the design to practical and resource constraints. The chosen jig was technically, safety, and production compliant, which helped efficient and reliable assembly at Company A. Stakeholders from PQE, Mold Engineering, Production Engineering, Assembly, Supervision, and Safety departments played a part in the evaluation. Pugh Matrix used during the final selection is presented in the Tables 1,2 and 3.

Table 1: Pugh Matrix criteria

Criteria	Score			Weighting	Final Score		
	Design A	Design B	Design C		Design A	Design B	Design C
Efficiency				3			
Performance				2			
Safety				2			
Cost				1			
Total							

Table 2: Weighting of criteria

Weighting	
3	Important
2	Moderate
1	Not important

Table 3: Score of criteria

Score	
5	Very High
4	High
3	Moderate
2	Low
1	Very Low

3.0 RESULTS AND DISCUSSION

To establish the most appropriate design for action, a Push Matrix was applied in comparing Design A, B and C about four main criteria, Efficiency, Performance, Safety and Cost. Each criterion was assigned weights, according to importance presented in table 2.

3.1 Design Analysis

As shown in Table 4, Design A received the highest score, 35 points, since it did well in Efficiency and Performance which are given the greatest importance. Safety & Ergonomics were a strong point too, allowing it to secure the top place. Then came Design C which scored 26, so it ended up being balanced yet fell short in a few aspects. Because Efficiency and Safety

were evaluated poorly, Design B scored less than other designs, even if it met the minimum requirements for 21 points. The team made certain that assembly wouldn't put operators in harm's way. The Design An option was selected first, since it was more secure and helped us lift fewer objects which decreased the risk of injuries. Because of its ergonomic design, the machine uses less energy and allows people to work safer.

Before anything else, the team made sure the solution was safe and worked well, not how affordable it was. All the designs had similar costs which made them all good options for development. Since we believe that the future will be better, we looked for an option that would stand out because of how efficient and few defects it offers.

Table 4: Design Criteria Decision

Criteria	Score			Weighting	Final Score		
	Design A	Design B	Design C		Design A	Design B	Design C
Efficiency	5	3	4	3	15	9	12
Performance	5	3	3	2	10	6	6
Safety	4	2	3	2	8	4	6
Cost	2	2	2	1	2	2	2
Total					35	21	26

In summary, Design A is best for carrying out the project since it shows the greatest effectiveness in productivity, security and global results.

3.2 Final Design

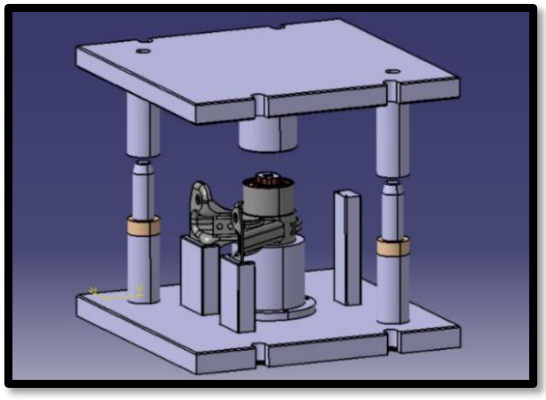

Figure 7: Final Design

Figure 8: New Rear Engine Mounting Jig

3.3 Data Cycle Time Before and After

CYCLE TIME					
Part Name	REAR ENGINE MOUNTING	Mold Code No	-	Mrp Code	P2/164
Part No	-	Trial No	① ② ③ ④ ⑤		
Customer	-	Machine ID	-		
Process	ASSEMBLY	Date	21/1/2025		
Starting Time	8.00 a.m.				
End Time	8.00 p.m.				

Process 1				
SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5
25.5	24.9	28.9	26.4	27.6
Average Time (sec)		26.66		

PROCESS 1	
OUTPUT PER HOUR	OUTPUT PER SHIFT
135	1384

Figure 9: Cycle time before

CYCLE TIME					
Part Name	REAR ENGINE MOUNTING	Mold Code No	-	Mrp Code	P2/164
Part No	-	Trial No	① ② ③ ④ ⑤		
Customer	-	Machine ID	SM		
Process	ASSEMBLY	Date	10/2/2025		
Starting Time	8.00 a.m.				
End Time	8.00 p.m.				

Process 1				
SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5
9.1	9	9.3	9.1	9.4
Average Time (sec)		9.18		

PROCESS 1	
OUTPUT PER HOUR	OUTPUT PER SHIFT
392	4020

Figure 10: Cycle time after

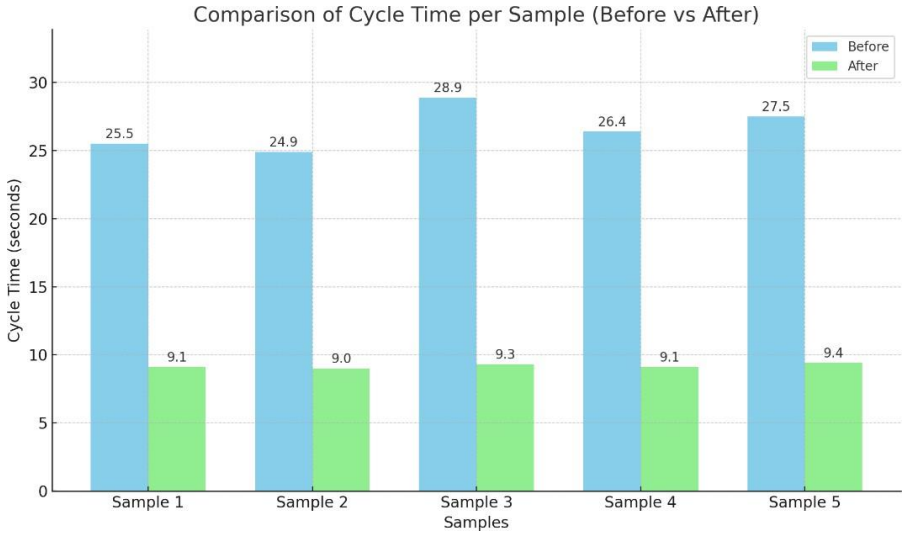

Figure 11: Comparison before and after implementation

A massive increase in efficiency was experienced in the Rear Engine Mounting Assembly process after comparison of cycle times before and after the process improvement. At first, the cycle times were between 24.9 and 28.9 seconds with an average of 26.66 seconds. This variation pointed inefficiencies, which most probably resulted from manual handling, bad ergonomics, or absence of proper tooling. With the introduction of the improvement – presumably the introduction of a dedicated jig – the cycle times have fallen off sharply to within 9.0 – 9.4 seconds, with an average of 9.18 seconds.

Such a decrease of more than 65% in the average cycle time emphasizes the effectiveness of the solution in optimizing process. It also ensued with a more standardized output, an indication of better standardization and control of the process. The result corresponds to the criteria of lean manufacturing and minimizes waste and enhances productivity while optimizing the assembly process and making it faster and more stable.

4.0 CONCLUSION

By using a special jig at Company A, productivity, safety and uniformity for the engine mounting process rose dramatically. By having a joint design, evaluation with the Pugh Matrix and observing what happens on the shop floor, the project delivered a practical answer that complied with lean manufacturing objectives. Because of the jig, cycling time placed less demand on workstations and increased the quality of the products by 67%, reaching just 9.18 seconds. By using this process, there is a stronger chance of better advances in making EV components.

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Development of a Karakuri Lifter Trolley for Center Engine Mounting Bush Transport to Assembly Machine

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ABSTRACT

The current Child Part (CP) transfer trolley requires feeders to adopt awkward body positions when filling with the child part to ensure a smooth assembly process. Prolonged working hours and repetitive bending can lead to fatigue among child part feeders after prolonged hours of work. This fatigue often results in a reduced feeding speed. To address this issue, the concept of a Karakuri lifter trolley been proposed to enhance the feeding position of child part feeders at assembly lines. The design of this trolley cames with a lifting platform which able to let the child part runner reach the platform of the trolley without major bending posture. A counterweight is added to the another end of the trolley to perform pulling force to the trolley platform. Three design been sketch out and selected using Pugh method based on selected criteria. The selected design be transfer to 3D design using CATIA. The design will be fabricated into real item. The outcome of implementing this trolley shows an improvement based on RULA assessment checklist where the RULA score shows a slight improvement from score 7 to score 6 after implemented with Karakuri trolley to child part runner. The lifting method had been changed from initially bending posture to standing posture to loading the first poly box reach the lifting platform to child part trolley. the recommendation from the overall finding perhaps to be a successor for the next Karakuri concept project used in assembly line in the future.

Keywords: karakuri trolley, ergonomic, working posture improvement, lifting mechanism

1.0 INTRODUCTION

High productivity and reduced expenses for operations are ensured currently in automotive manufacturing by the productivity and safety of material handling systems. Manual component transportation frequently results in ineffectiveness, operator fatigue, and an elevated risk of injury, especially in high-volume manufacturing lines. The center engine mounting bush is one such part; this is a small but essential part that needs to be handled properly before being transferred to the assembly machine.

The Japanese lean manufacturing method known as Karakuri Kaizen (Porteiro Paraponiaris & Mateos Rodríguez, 2019) places a strong emphasis on using basic mechanical systems that leverage human motion, gravity, and counterweights to generate energy without the need for external power sources. By providing low-cost, energy-free, and low-maintenance solutions to automate repetitive processes, this strategy fits in nicely with the objectives of sustainable manufacturing.

In order to transport the center engine mounting bushes from the storage area to the assembly machine, this thesis investigates the design and construction of a Karakuri lifter trolley. The idea put forward aims to enhance worker ergonomics, reduce manual labor, and boost production line efficiency overall. To provide a practical and economical solution, the project combines the concepts of ergonomic analysis, lean manufacturing, and mechanical design.

This study aims to improve child part runner working position by improvement in ergonomic factor. Currently, the child part runner practicing non-proper lifting technique which cause fatigue to child part runner after prolonged working hours. Prolonged working hours may cause the child part runner facing physical strain on the shoulder, upper limbs and lower back. Reduction of speed for the feeding workstation may cause effect to operator productivity where potentially causes 1 or 2 pieces of productivity losses by the operator while need to feed the lines by themselves while child part runner is not available to serve the operator.

2.0 METHODOLOGY

2.1 Investigation on Working Posture

Providing an ergonomic working posture improvement is the main idea of this project study. The gemba is required to investigate what is the current situation of child part transportation between child part storage area to workstation. During gemba in production line, the working posture of the child part runner had been investigate and find out the working posture of the child part feeder is not in good posture as shown in Figure 1. The child part runner need to bend body to locate the child part poly box onto child part trolley. This movement been analyzed using RULA check sheet shows in Figure 2 to find out the position marks of the working posture of the child part runner. The RULA analysis been conducted with given marks based on the working posture.

Figure 1: Child part runner loading child part poly box to current trolley

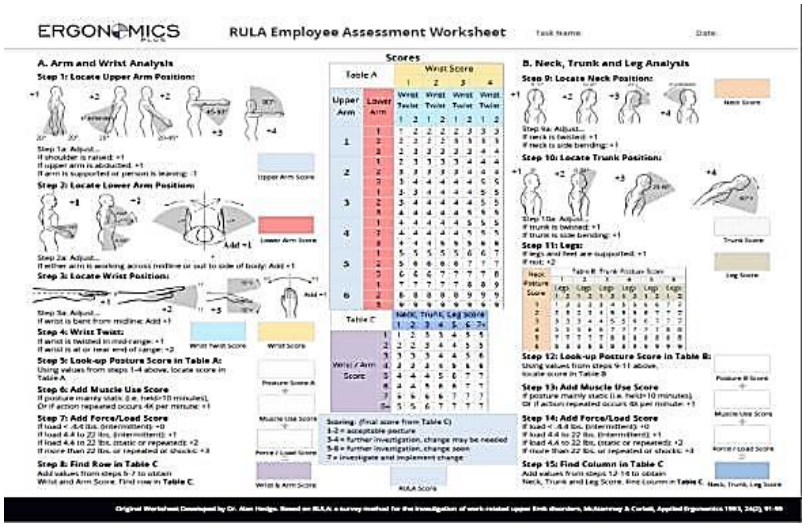

Figure 2: RULA assessment check sheet

2.2 Ishikawa Study on Main Cause Child Part Runner Practicing Non- Proper Lifting Technique

To identified the main cause of the problem why child part runner practicing non-proper working posture, ishikawa diagram or known as fishbone diagram been used to explore and illustrate the cause and effect relationship from the main idea problem. (Botezatu et al., 2019) The main problem of the idea been listed down at the fishbone head while the spine bone used to discover out the real root cause of the problem. The developed problem able to act as a guide line for the problem solving in this case.

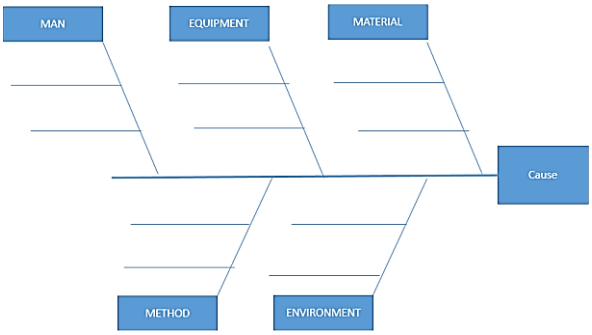

Figure 3: Ishikawa diagram

2.3 Design Sketching and Conceptual Design Selection Using Pugh Matrix

The design of the trolley firstly come with a conceptual design sketching. There were 3 sketching been sketched out shown in Figure 4 (a), (b) and (c) to find out which is the best design to be fabricated. During design stage, automation team suggest to convert an abandoned lifter trolley to save time and cost shown in Figure 4 (b). This convert involve changes from electrical energy to gravitational energy. This lifter trolley chassis still in good condition. The reason of been abandoned is due to broken down electrical system and breakage of the driven chain of the lifting mechanism. The repair cost of the electrical system already overbudget cause the section owner decide to declare total loss on the trolley and abandoned the trolley.

In Figure 4 (a), this trolley have a simple body frame construction with a simple lifting platform. This platform is controlled by using 2 counter weight which hung at each of the pulling cable at the back to pull up the platform. This utilize 2 linear bearing for up and down movement at each pole of the trolley. A reinforcement is added to support the frame from lifting heavy weight. This design concept utilize a lighter and lesser material to used in fabrication which befits to total fabrication cost. In Figure 4 (b), this trolley converted from an abandoned trolley frame which initially battery powered with electrical motor to operate with Karakuri concept which using counter weight to perform lifting movement of the platform. This trolley give a big benefits in fabrication cost as the cost of purchasing material of the trolley chassis, caster wheel, lifting mechanism and etc. able to be cut down where the main frame and chassis of the trolley is in good condition. The cost will be at purchasing material for the Karakuri conversion to the trolley. In Figure 4 (c), this trolley have a more complex building and also involved with more parts compared to Figure 4 (a) in the chassis fabrication. This design utilize double pole of the chassis as support to lifting mechanism for the platform. This trolley utilize spring to pull the platform up and down while loading and unloading child part poly box to trolley. A complex pulley system been used aim to increase the force load (Aslan Seyhan, 2022) of the pulley system to pull up the platform by spring energy. The bearing used in lifting mechanism utilize a double bearing to rolled along with double pole of the chassis.

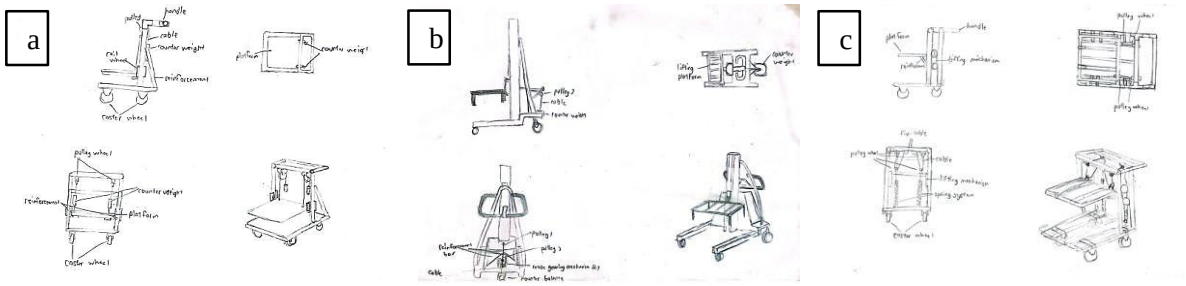

Figure 4: (a) Design 1, (b) Design 2, (c) Design 3

The selection of design had been identified using Pugh matrix (Von Teh et al., 2020) shown in Table 1 which generated by discussion between team. The sketch which get the highest mark taken as the final design to be fabricate. The selected sketch been designed using CATIA V5 software to show out the dimension of the actual product and able to show the sketch concept into 3D model through the software. The fabrication of the trolley used the drawing from CATIA as draft model.

2.4 Fabrication Process of The Karakuri Trolley

The trolley was towed back for conversation work and find out the hidden damage on the trolley. The electrical system and the electric motor been dismantled where this electrical component not be used in this trolley. The remain mechanical component used to be investigate for the damage or reusability. The pulley system remain in a good condition which doesn't need to be repaired. The chain of the trolley had broken which need to be repaired for future usage. A chain connector used to reattach the chain to test the smoothness of the rail for the lifting mechanism. Initially, the chain reattach with the lifter which works along with electrical motor to control the lifting movement of the lifter. The chain later had been pull out to be attach with counter weight to control the movement of the lifter. After smoothness check, the rail found out have some stuck at the lower deck. A stopper be planned to weld on the rail chassis to control the maximum lowering level. A demarcation been marked on the chassis at the level need to weld with the stopper. After discussion with maintenance team, the rail chassis can't be welded because of aluminum material used on the rail chassis. Another stopper idea provided by maintenance team. The stopper will be welded to platform which ease to be welded due to iron material.

Fabrication on lost part been fabricate by finding recycle items at recycle area. A frame to be used as lifting platform been found at the recycle area and took back for further fabrication. A stopper and a bracket to screw up to the lifting mechanism of the trolley need to be welded before usage. The chain needs to be repaired and the chain arrangement need to find out the new way for the chain to moving using the already build in gear system. For the counter weight, decision of using stop production mold as the counter weight to reduce initial development cost.

2.5 Data Collection

The required data been collected after the trolley be introduced to child part runner. The assessment of the body posture able to be analyzed to find out the improvement before and after utilize the child part trolley. The body posture assessment able to be investigate during implementation of the Karakuri trolley to

3.0 RESULTS AND DISCUSSION

3.1 Ishikawa Analysis Result

Ishikawa diagram is conducted to find out the root cause of the child part runner for practicing the non proper lifting technique. Based on Figure 5, the root cause of the child part runner been identified in 5 cause which is man, equipment, material, method and environment. In this study, the root cause will be more focus on equipment factor. The current equipment used doesn't have a lifting mechanism to ease the loading child part poly box.

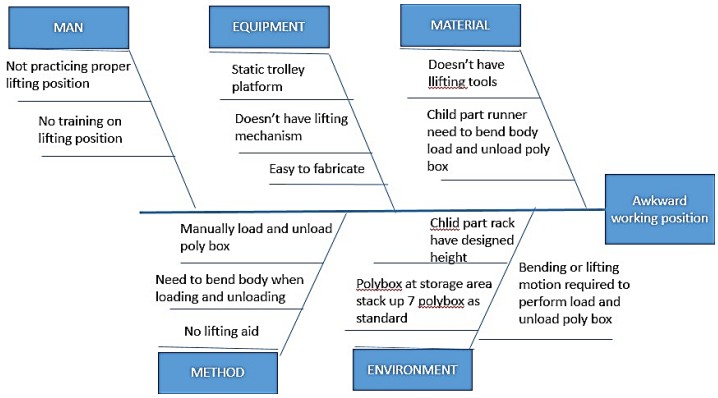

Figure 5: Ishikawa diagram of child part runner praticing non proper lifting technique

3.2 Pugh Method Decision

Pugh method is used to made decision with the criteria to select the best design to be fabricate. The selected criteria is based on ergonomic, ease to operate, ease in maintenance, constriction simplicity and estimated total fabrication cost and load carry ability. The decision evaluation been evaluate based on the design sketching proposed shown at Figure 4. The evaluation mark is determined by using answer key which used to indicate the score. The answer key indication been marked as 1, not meet criteria; 2, slightly meet criteria; 3, meet criteria moderately; 4, almost meet criteria; 5, meet criteria

Table 1: Marking decision by using Pugh method

Criteria	Design 1	Design 2	Design 3
Ease to operate	4	4	4
Ease in maintenance	3	3	3
Construction simplicity	2	3	2
Estimated total fabrication cost	3	4	3
Total	12	14	12

Based on the Table 1, the design 2 provided with the highest score. This indicates that design 2 will be selected as the model to be fabricated.

3.3 Working Posture Comparison Result

In side of working posture, the working posture of the child part runner have shown an improvement by using karakuri trolley. The significant of the loading posture changes shows

in the first polybox to be loaded. In Figure 2, the child part runner need to bend down body to loading child part poly box to trolley. Even the child part runner had load to third layer of child part poly box, the body posture of the child part runner still need to bend down gradually to load up child part poly box to the current trolley. By using Karakuri lifter trolley, the body posture shows an improvement to loading posture for the first poly box shown in Figure 3. The loading posture of the child part runner shows slightly bend down body to load the first poly box

a

b

Figure 6 (a) child part runner using current trolley, (b) child part runner using Karakuri trolley

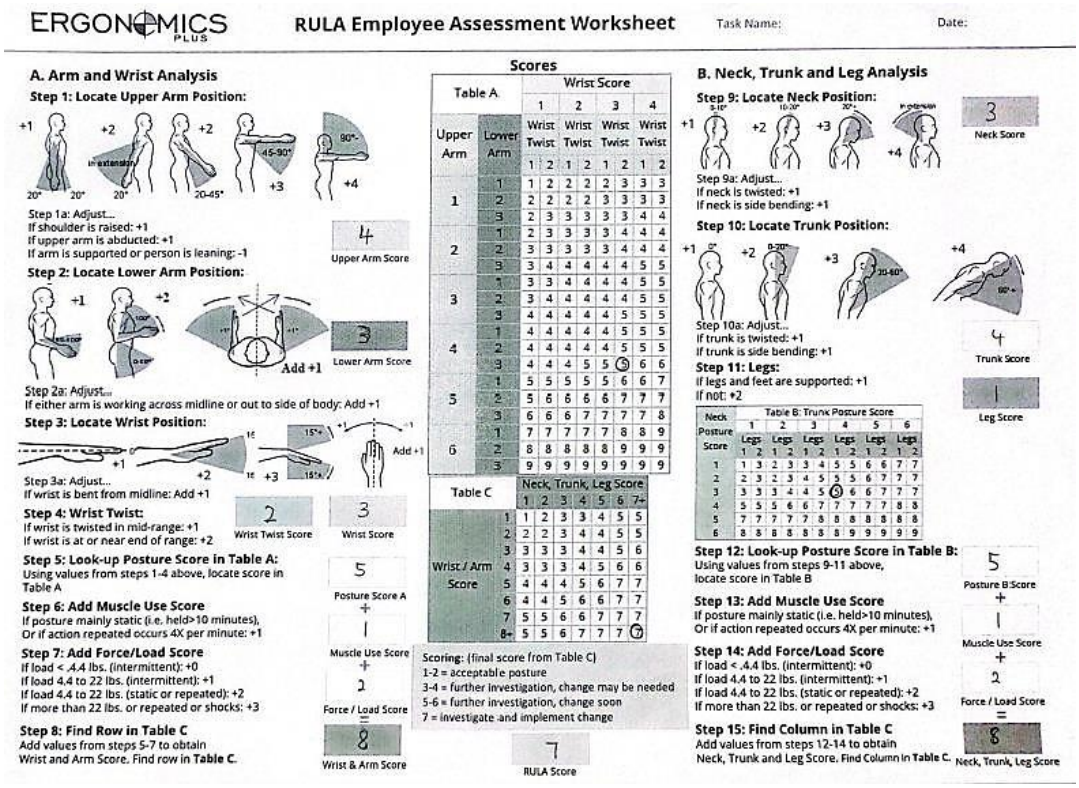

Figure 7: RULA check sheet before improvement

In Figure 7, this shows the RULA assessment done based on Figure 6 (a). In arm and wrist analysis. The arm angle had been raised to 90^0 at the upper arm let the upper arm scored with

4 and the lower arm extension had more than 100^0 let to be scored with 2. The lower arm shows bend out from the body midline which add on another 1 score to lower arm score with total up a score of 3 in this section. For the wrist position, the wrist bending shows larger than 15^0 which let the wrist score of 3 and score of 2 to wrist twist where the wrist is at or near end of mid range. The total score of the arm and wrist position scored with 5 from Table A shows in Figure 7. In muscle score and force/ load score in arm and wrist position, the muscle score received score of 1 where the action is repetitive occur four times per minutes and score 2 for force/ load score where the load of the poly box with child part is between 2 kilogram to 10 kilogram for each poly box with repeated motion. A total wrist and arm score recorded with score of 8.

In neck, trunk and leg analysis. The neck posture of the child part runner shows bend down more than 20^0, receiving score of 3. The trunk position bending more than 60^0 to reach the platform of the trolley let this section receiving score of 4. The leg scored with 1 where the legs and feet were both supported on the floor. The total score of the trunk posture score scored with 5 from Table B shows in Figure 7. In muscle score and force/ load score in trunk position, Both of the score remain same as in muscle score and force/ load score in arm and wrist position. A total wrist and arm score recorded with score of 8.

By collecting score from Table A and Table B in Figure 7, the RULA score has been found out with a score of 7 which need investigate and implement changes.

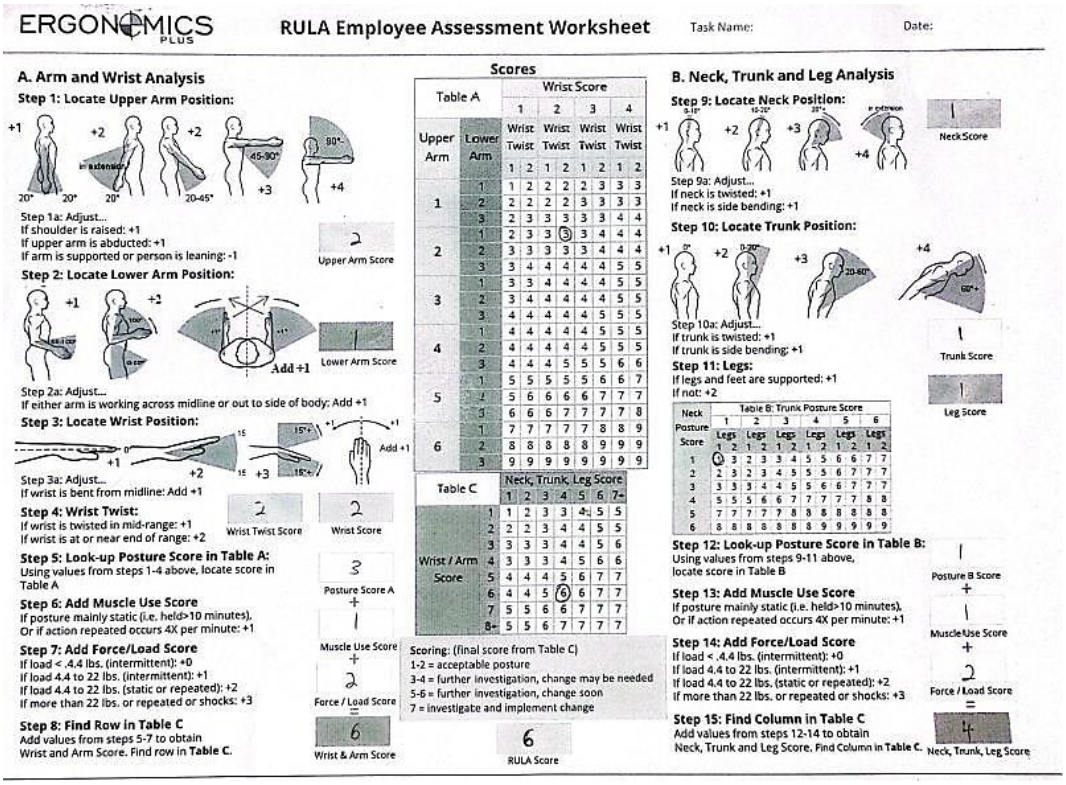

Figure 8: RULA check sheet after improvement

In Figure 8, this shows the RULA assessment done based on Figure 6 (b). In arm and wrist analysis. The arm angle had reduced to 20^0-45^0 at the upper arm, reduce score of 4 to 2. Lower arm extension had reduce to moving between 60^0 to 100^0 shows a reduction score from 2 to 1. Due to lower arm didn't bend out from the body midline where the total up a score reduced

from 3 to 2 in this section. For the wrist position, the wrist bending angle reduce to between15^0 reduce the wrist score of 3 to 2 and wrist twist score remain 2 where the wrist is at or near end of mid range. The total score of the arm and wrist position scored reduce from 5 at Table A shows in Figure 8. In muscle score and force/ load score in arm and wrist position, the muscle score and force/ load score remain same where the working way and the weight of the poly box remain the same which add score1 at muscle score and 2 at force/ load score. A total wrist and arm score reduced from score of 8 to 6.

In neck, trunk and leg analysis. The neck posture of the child part runner shows a bending between than 0^0-10^0, reduce score of 3 to 1. The trunk position had be corrected to straight posture which from bending more than 60^0 to standing with 0^0 posture to reach the platform of the trolley reduce the score of 4 to 1. The leg score remain with 1 where the legs and feet were both supported on the floor. The total score of the trunk posture score scored with 1 from Table B shows in Figure 8. In muscle score and force/ load score in trunk position, the muscle score and force/ load score remain same where the working way and the weight of the poly box remain the same which add score1 at muscle score and 2 at force/ load score. A total wrist and arm score reduced from score of 8 to score of 4.

By collecting score from Table A and Table B in Figure 8, the RULA score has been found out improved from score of 7 to score of 6. The improvement didn't shows a significant improvement where the same muscle score and force/load score before and after had add on score of 3 on both side of body posture analysis. This add on score let the RULA score didn't shows a significant improvement.

3.4 Cycle Time Study Comparison Result

A cycle time study had been conducted to find out the comparison between using current trolley and Karakuri trolley. The time study is conducted from loading poly box to platform, transfer to workstation then unload the poly box. Due to the space between poly box pallet had been narrowed during fabrication of the trolley from machine relocation activity at shop floor. This study been transferred to a wider space to conduct the time study for having a more comparative data. The flow of conducting the time study shown in Figure 7. Figure 8 (a), (b) and (c) shows how child part runner perform using the Karakuri trolley.

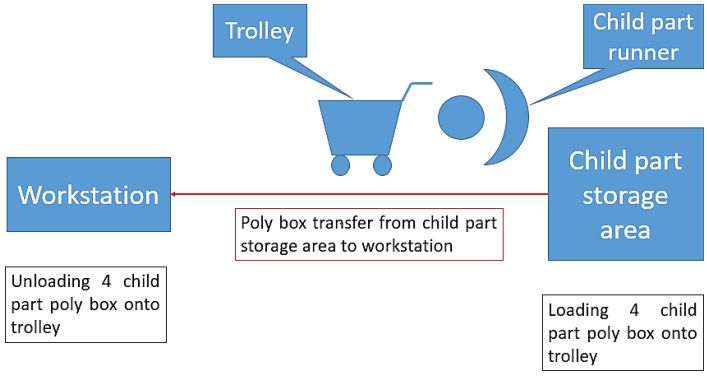

Figure 7: Map flow of child part runner transfer poly box to workstation

a b c

Figure 8 (a) loading poly box to platform, (b) transfer to workstation,
(c) unloading poly box to workstation

In cycle time comparison between current trolley with Karakuri trolley, the time taken is based on 4 times loading and unloading child part poly box which 4 poly box. In the cycle time comparison, the utilization of Karakuri trolley shows slightly delayed where the child part runner didn't immediately release the poly box after located to the trolley platform where this platform is a moving platform. Compared to current trolley, the child part runner able to release the poly box once located on the platform due to static platform and years of using the current trolley which have a more confidence in release the poly box once the poly box had reach the platform. In other hand, the size and construction of the Karakuri trolley is larger and wider let the child part runner need some time to reach the handle of the trolley compared to the current trolley where child part runner drive the trolley by pulling and pushing of the poly box on the trolley. This comparison data shown in Table 2

Table 2: Time comparison between using current trolley and Karakuri trolley

Cycle time comparison			
Current trolley		Karakuri trolley	
Activity	Time required (s)	Activity	Time required (s)
Loading 4 poly box	15	Loading 4 poly box	17
Travel from child part storage area to workstation	12	Travel from child part storage area to workstation	15
Unloading 4 poly box	13	Unloading 4 poly box	15
Total	40	Total	47

4.0 CONCLUSION

As a wrap, the child's part runner's working posture has improved significantly as a result of the construction and use of a Karakuri cart. The implementation of Karakuri system to trolley lessens the requirement for non-proper lifting postures, repetitive bending, and lifting that are frequently connected to manual material handling by implementing ergonomic design concepts. This helps in ease the working method of the child part runner as the reach distance of the child part runner to the trolley platform had been decreased. In future, the Karakuri trolley might become the role model as idea for future Karakuri concepted trolley or lifter device as this Karakuri trolley is the first Karakuri trolley to be fabricated at production line.

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Digital Systems Transitions for Enhanced Manufacturing Quality Control

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ABSTRACT

This study investigates how the quality control (QC) reporting system for armrest production at Company X is being digitally transformed, specifically by replacing manual check sheet methods with a barcode scanning system. The current manual process, reliant on physical checksheets, limits efficiency with an average cycle time of 28.1 seconds per unit and restricts daily reporting capacity to approximately 960 units. The study found important problems, like slow processes and dependence on paper documents, by using methods such as observing work practices, analysing causes of issues with the Ishikawa Diagram, and measuring time taken for tasks. The implementation of a barcode scanning system, integrated with cloud storage and live data visualisation via Looker Studio, significantly reduced the cycle time to about 12 seconds per unit, a 56.9% improvement. This reduction more than doubled production throughput, enabling approximately 2,230 units to be processed in the same time previously required for 960 units. The digital system enhanced data accuracy, minimized manual entry errors, and supported timely decision-making through real-time monitoring. Findings demonstrate that digitalisation not only streamlines data input but also boosts operational efficiency and productivity within manufacturing QC processes. The study concludes that the continuous optimisation and expansion of digital tools are vital to maintaining competitive advantages in modern manufacturing environments.

Keywords: digital transformation, quality control, real-time monitoring, time-study

1.0 INTRODUCTION

Digital solutions in manufacturing have been shown to reduce reporting time significantly and improve data reliability, thereby supporting better quality management and operational performance (Lundén, N. 2022), where The quality control (QC) process for JL armrests at Company X, currently relies on manual data collection using physical check sheets. Operators monitor key product quality metrics such as Units Per Hour (UPH) and assess operator performance by recording data manually for each product release.

The process flow begins with glue spraying, followed by drying, oven curing, wrapping, and stapling. Following stapling, QC inspections will document and annotate the data in the checksheet. In the event of any defective items, the QC inspector will allocate them to the rework area rack. While this manual approach is straightforward, it introduces several challenges, including slower production record and delays in data analysis. These issues adversely affect overall productivity and manufacturing line efficiency. This study aims to implement digitalization on the QC reporting system to reduce cycle times.

Shown in the Figure 1 , currently the manual reporting checksheet need an average of 28 seconds per part, limiting daily recording capacity to approximately 960 units. The project focus on transforming the QC reporting station from manual and semi-digital methods to a fully digital system, with the goal of streamlining operations and enhancing data accuracy.

Figure 1 : Checksheet paper

1.0 METHODOLOGY

2.1 Gemba Walk

The Gemba Walk was a practical method for managers to directly observe quality control work on the production floor and communicate with workers (Imai, 2019). It helped identify real problems such as delays, missing tools, or unclear steps that were not always evident in reports. By witnessing the process firsthand and collecting feedback, managers found simple improvements like adding automation, upgrading tools, or updating procedures. This approach encouraged teamwork and created solutions that suited the actual work environment. (Liker & Hoseus, 2020).

2.2 Ishikawa Diagram

The Ishikawa Diagram helped identify root causes (Pietsch et al., 2024). Analysis using the Ishikawa diagram revealed four main factors, as shown in Figure 2. First, under Method, work processes were time-consuming, causing frequent overtime. Second, the Man factor showed over-reliance on team leaders for updates, leading to communication delays and inefficiencies (Ito et al., 2022).

Third, the Machine category highlighted limited technology integration in task tracking, reducing real-time production control (Tayal et al., 2021). Lastly, the Material category pointed to paper-based documentation as a source of extra cost and waste. These findings, based on observations and team feedback, guided the digital transformation initiative.

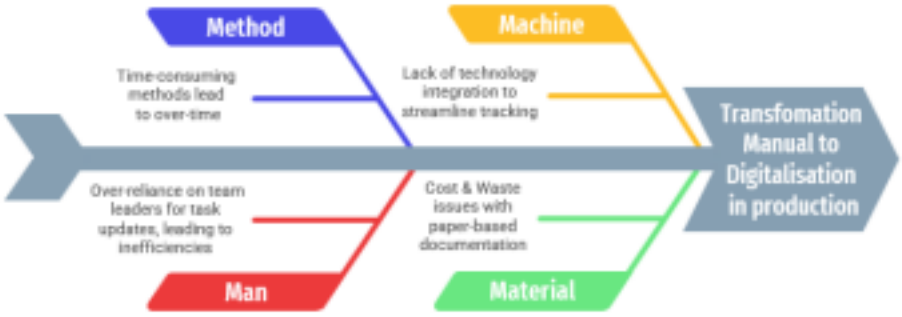

Figure 2: Ishikawa diagram on transformation manual to digitalisation in production

1.1 Time Study

A time study is a systematic method used to measure how long different tasks take to identify delays and areas for improvement (Niebel & Freivalds, 2021). In this study, data were collected using a stopwatch to accurately record the time operators spent on key activities. This included tasks such as defect inspection, task tracking, and reporting.

1.2 System Digitalization

Digital transition shown in Figure 3, constitutes a paradigm shift in manufacturing, moving from conventional, often siloed, quality control methods to interconnected, data-driven ecosystems (Jones et al., 2021). To reduce the long cycle time in the current process, a barcode scanning system was introduced to simplify data entry. Barcode labels were placed on parts, and operators used handheld scanners, as shown in Figure 4, to quickly capture information like operator ID, part number, and product quality. Each part received a unique barcode that tracked it through production.

The scanned data was automatically sent to the cloud for central storage and real-time access. This information was then linked to Looker Studio, shown in Figure 5, for live monitoring and analysis. Using this system lowered mistakes, sped up data recording, and cut cycle time compared to the manual checksheet method (Istiqomah, Sansabilla, Himawan, & Rifni, 2020) ,Pilot tests will assess how well the system works.

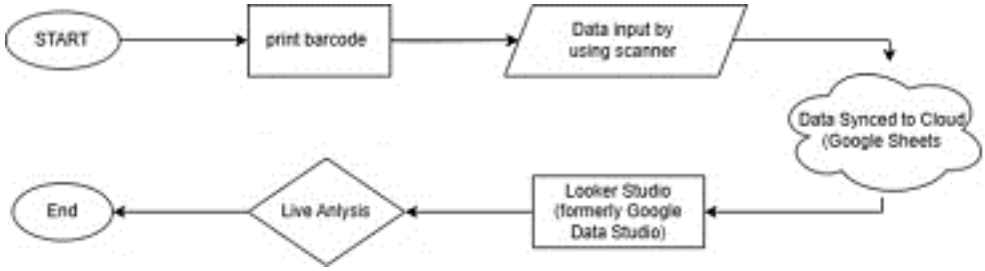

Figure 3: Flowchart of digitalisation system

Figure 4: Process scanner

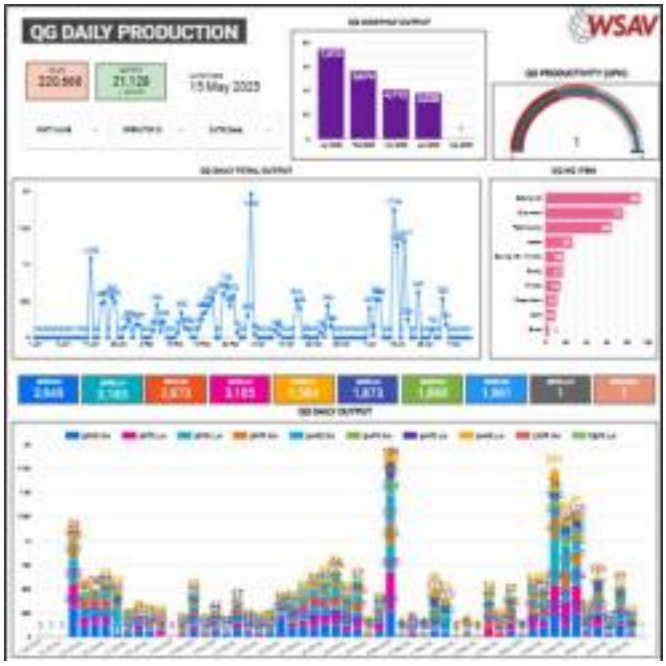

Figure 5: Dashboard for live monitoring

3.0 RESULTS AND DISCUSSION

3.1 Time Study Before digitalization system

The bar chart depicts the average time (in seconds) spent on different activities associated with completing a manual checksheet during a 14-day period. The work sequence are color-coded "Check the work to ensure process" (blue), "Tick that line as good or not" (green), "Look for checklist apply elements GOOD or NG" (purple), and so on. Among these, "Check the work to ensure process" consistently spent the most time each day, accounting for around 60-65% of the overall job time.

Specifically, on day 8, the total duration peaked at more than 33 seconds, the highest recorded number, but on Day 10, it dropped to just over 25 seconds. This variation creates a 24.24% discrepancy between the highest and lowest recorded days. These variations shows that manual handling tasks may introduce inconsistencies in time performance, aligning with (Rothmore et al. 2023), who highlighted the impact of manual handling on task performance variability..

Furthermore, the purple area, which represents "look for the part If (Ng) need to tick down the specific name of the issue and rework or remake," was the second most time-consuming job, accounting for around 20–25% of the overall time. Conversely, the smallest fraction across all days was constantly "Tick and report to the checksheet," accounting for just approximately 2-4%. The average time spent throughout all 14 days is 28.1 seconds, as indicated by the callout on the upper right of the graphic. These findings indicate that a lot of manual decision-making is needed in the quality assurance process, which can lead to delays and inconsistencies.This showing that unstandardized manual tasks often cause time waste and mistakes (O'Sullivan et al. 2021). They advocate introducing lean manufacturing processes or digital check systems to increase performance dependability.

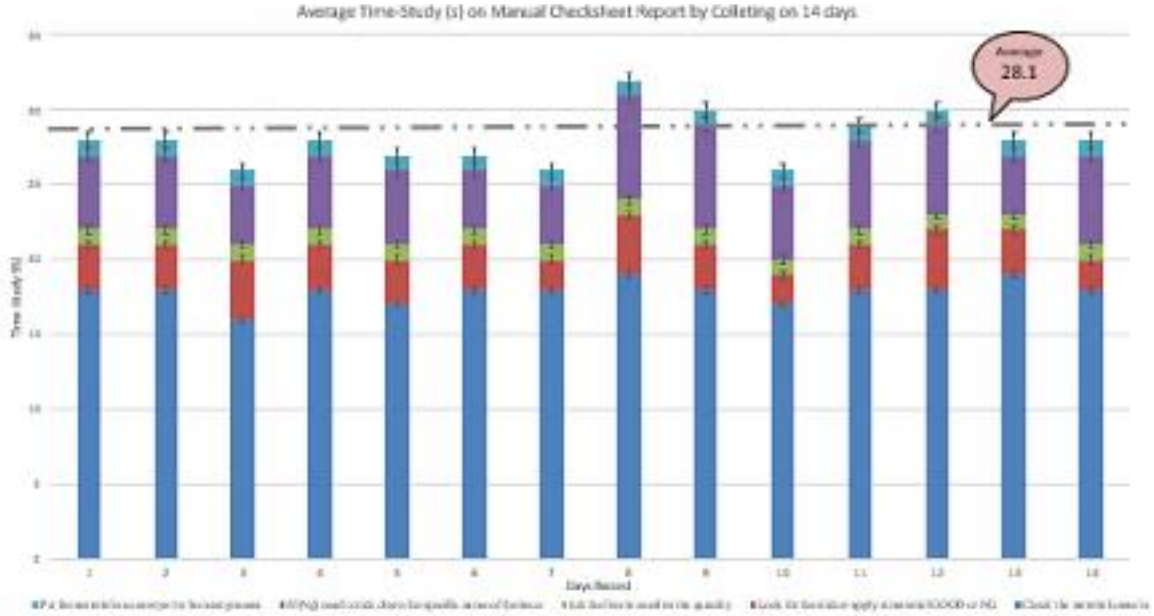

Figure 6: Bar chart on cycle time every work sequence before digitalization for 14 days

3.2 Comparing before and after digitalization system

The comparison of cycle times between the manual checksheet report and the digitalization system shown on the Figure 7,where the manual checksheet method took an average of approximately 28.1 seconds per unit, while the digitalization system reduced the cycle time to about 12 seconds. Result represents a significant reduction of around 56.9% in cycle-time. The time reduction can be attributed to the automation and real-time data capture offered by the digital system, which eliminates manual entry errors and speeds up the recording process.

Similar findings have been reported by (Istiqomah, Sansabilla, Himawan, & Rifni, 2020), where barcode scanning and automated data collection significantly improved process efficiency in manufacturing by reducing delays and minimizing human dependency. This decrease in cycle time has practical implications: if the original time for one unit was 28.1 seconds, allowing production of 960 units in a day, the digital system can complete approximately 2230 units in the same timeframe. It improve more than doubles the productivity without increasing labor or operational hours, demonstrating the substantial impact of digital transformation on quality control processes.

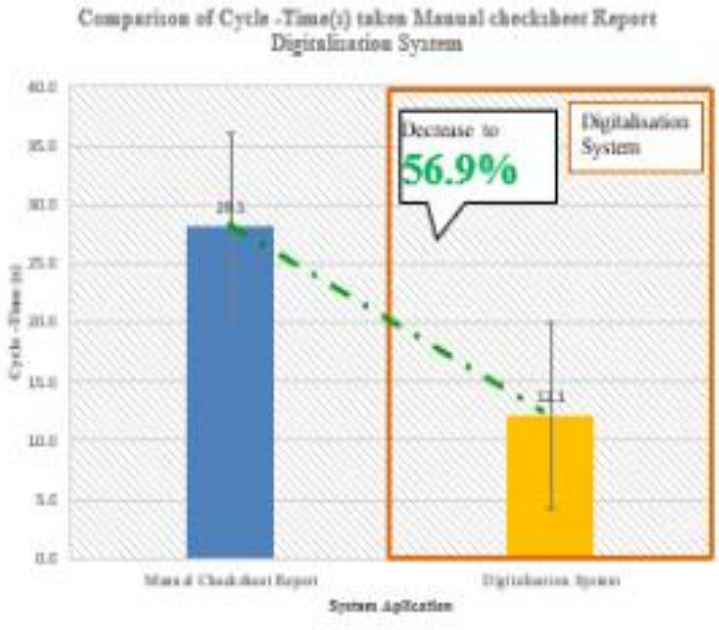

Figure 7 : Comparison result of time study manual checksheet to digitalisation system

4.0 CONCLUSION

The implementation of the barcode scanner system has demonstrated substantial effectiveness in streamlining data input processes on the production line. Compared to traditional manual checksheets, the barcode scanner significantly reduced cycle time from over 28.1 seconds to approximately 12.1 seconds, marking a notable improvement in operational efficiency. This reduction save time and boost daily reporting capacity by eliminating error and delays associated with manual data entry.

The marked improvement in cycle time corresponds directly with enhanced productivity. By reducing the time required per input task by roughly 56.9%, operators are able to process approximately 2,230 units within the same working period, compared to 960 units previously. This increase in throughput reduces bottlenecks in the quality control stage and accelerates production flow. Moreover, the rapid data capture enables more timely and accurate reporting, thereby supporting improved decision-making and process monitoring

In conclusion, adopting a barcode scanning system aligns with broader digital transformation goals in manufacturing by facilitating real-time data capture, improving data accuracy, and enhancing operational efficiency. From the study (Xue, Zhao, & Tan, 2022) highlights the importance of boundary spanning behaviors in leveraging digital transformation to achieve competitive advantage. These insights underscore the need for continuous optimization and integration of digital technologies to enhance production line performance and maintain a competitive edge**.**

ACKNOWLEDGMENT

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identifying key areas for improvement in the injection molding process. Sincere thanks are also due to the academic supervisor from Politeknik Sultan Azlan Shah for their unwavering support, insightful feedback, and expert guidance throughout the duration of this project.

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Enhancing Productivity for Panel Fronts Seat Back using Die-Cut

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ABSTRACT
This study investigates the implementation of die-cutting process aimed at enhancing productivity and cost efficiency in the manufacturing of the panel front seat back for the RU Pacifica model at Company W. The conventional die-cutting operation was associated with prolonged cycle times and elevated production costs. To address these inefficiencies, a custom die-cutting system utilizing the Konwa KW-TD 200 machine was introduced. The intervention yielded a substantial reduction in cycle time from 45.2 seconds to 29.2 seconds, representing a 34.4% improvement. Additionally, a comprehensive cost analysis revealed a decrease in unit production cost from RM2.27 to RM1.16, corresponding to a 48.89% cost saving. Data collection involved time study check sheets measure using Casio hs-70w stopwatch and control charts to monitor changes in productivity and cost trends. The findings support the die-cutting process as an effective strategy for minimizing operational inefficiencies, offering a scalable model for similar manufacturing environments.

Keywords: cycle time, cost, enhancing productivity, konwa kw-td 200, check sheet, casio hs-70w.

1.0 INTRODUCTION

The panel front is a part of a car's interior that covers the front section, like the dashboard or door area, and gives it a neat and finished look and RU Pacifica is a mini van model made by Stellantis under the Chrysler brand. It is built on the RU platform and is known for its spacious interior, modern features, and comfortable design, making it a popular choice for families (M., Aziz, K., and Yusof, M. (2023). The research will adopt a mixed-methods approach, combining both qualitative and quantitative data to provide a comprehensive analysis of the existing processes such as check sheet.

A die-cut is a tool used to cut materials into specific shapes with high accuracy (Ascend-tech (2022). In this process, the raw material is placed on the machine, and the die-cut helps the cutting tool to ensure the correct shape is made every time (Prandit, H. (2022). This study will focus on panel front for RU pacifica. To enhance competitiveness in a demanding industry, the need to reduce costs, improve product quality, and gain greater control over production. The company faced challenges with high operational costs, longer cycle times, and limited flexibility. In response, initiating an in-house manufacturing solution through the development and implementation of a custom die-cut. This project aims to enhance productivity for panel front seat back.

2.0 METHODOLOGY
This research methodology outlines the structured approach used to investigate and improve the die-cutting process for the RU Pacifica panel front. The main objective is to analyze the current production method, identify inefficiencies, and implement improvements that enhance productivity and reduce costs. A mixed-methods approach was adopted, combining both qualitative and quantitative data to ensure a comprehensive evaluation of the die-cutting

process. To identify and address the root causes of production inefficiencies, the The Konwa KW-TD 200 die-cutting machine was used for the in-house implementation, selected for its precision and suitability for PP sheet materials used in the RU Pacifica panel front. Quantitative data was collected using a time measurement check sheet in figure 1, which recorded the production cycle time across ten production iterations. Cycle time was collected using Casio hs-70w stopwatch as shown in in figure 1 (A.K. Tiwari, A.R. Singh 2020). This data helped identify delays in manual handling, die-cut setup, and shipment time. On average, the cycle time was reduced from 45.2 seconds (outsourced) to 29.2 seconds after implementation of the die-cut an improvement of 34.4%**.** Additionally, control charts were used to compare the monthly cost per unit before and after the die-cut implementation. These charts provided visual insights into fluctuations and trends, confirming a cost reduction from RM2.27 to RM1.16 per unit an 48.89% savings (Industry, Elsevier, 2019)(Fabio Kerstens, Angelo Cervone 2020).

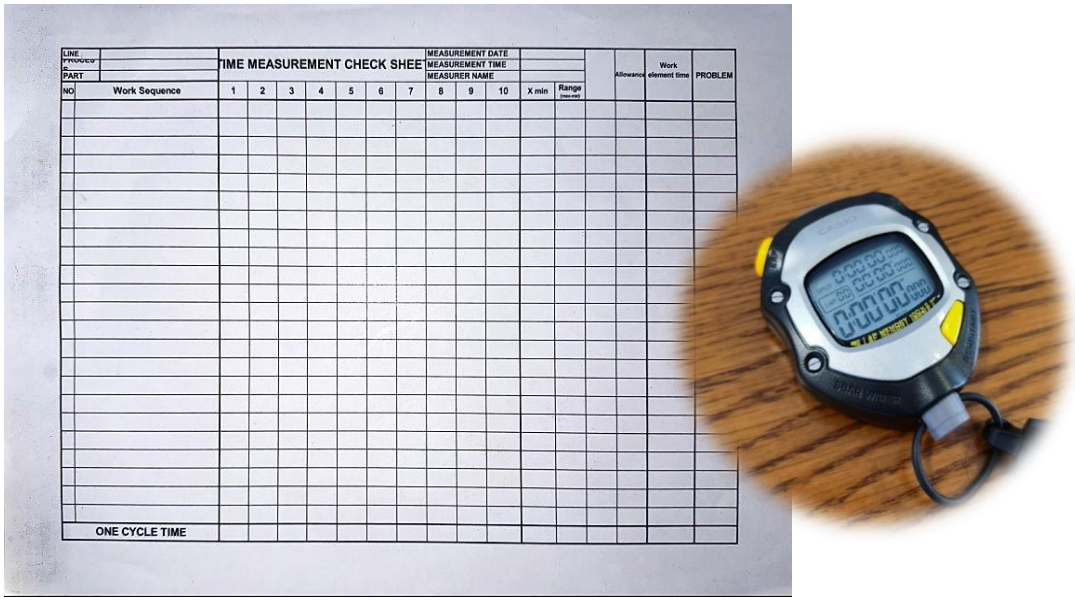


Figure 1: Check sheet for the cycle time study measure using Casio hs-70w stopwatch

Quantitative data was collected using a time measurement check sheet as shown in figure 1, which recorded the production cycle time across ten production iterations. The time study have been measure using Casio hs-70w stopwatch (A.K. Tiwari, A.R. Singh 2020).

Table 1 Cost per unit of panel front

Part Number	Part Name	Unit price	UOM
6-4367RU	sheet (456 x 194mm)	2.277	Pcs

Source: Company W material cost (2025)

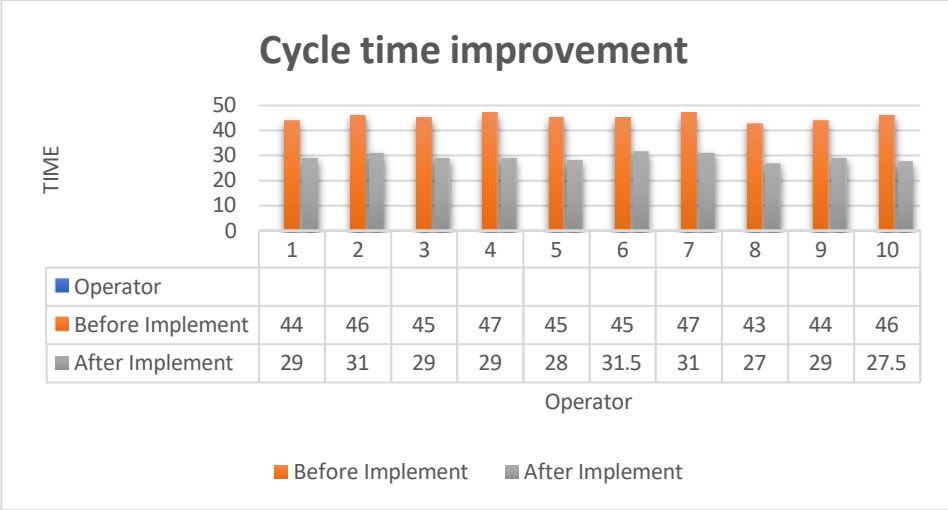
The material features in table 1 show a sandy or embossed texture, giving its surface a slightly rough or patterned feel. This design enhances grip and prevents slipping, making the product more functional and safe to use.

3.0 RESULTS AND DISCUSSION

3.1 Cycle Time Analysis

Reducing cycle time in the die-cutting process for the RU Pacifica panel front was a key objective of this study. Initially, the average cycle time was 45.2 seconds due to manual handling and inconsistent cutting. This limitation forced WSA Venture to depend on third-party production, increasing shipment costs and extending the lead time by one week.

After the implementation of the die-cut, the cycle time was reduced to 29.2 seconds, achieving a 34.4% improvement. This enhancement eliminated the need for third-party support, reduced operational costs, and shortened the overall lead time, contributing to more efficient and cost-effective production.



Operator	1	2	3	4	5	6	7	8	9	10
Before Implement	44	46	45	47	45	45	47	43	44	46
After Implement	29	31	29	29	28	31.5	31	27	29	27.5

Figure 2: Cycle time before implement the die-cut

Figure 1 shows the detailed breakdown of cycle time to produce the RU Pacifica panel front prior to the implementation of the die-cut. Data collected across ten production cycles revealed that the total cycle time per part ranged between approximately 45 to 47 seconds.

The major activities contributing to the overall cycle time included work sequence preparation, material setup, die-cut positioning, and manual handling of parts, with "Shipment Time for two products" occupying the largest portion.

3.2 Cost Produce per month

3.2.1 Electricity cost

$$11kkk \times 5 = 55kkkh\ per\ day$$

$$55kkkh \times 20 = 1100\ kkkh\ per\ month$$

$$1100\ kkkh \times RM\ 0.456 = RM\ 501.82\ average\ Electricity\ cost\ for\ 1\ month$$

$$(RM501.82 \div 20) \div 1000 = RM\ 0.025\ Sen\ electricity\ cost\ for\ 1\ panel\ front$$

3.2.2 Manpower cost

$$1800 \div 20 = 90\ Per\ day$$

$$90\ \div 1000\ pcs\ per\ day = RM\ 0.09\ sen\ average\ salary\ for\ 1\ Panel\ front$$

The labor cost for producing one piece of Panel front seat backs sheet is determined based on the worker's daily wage and the average production output. Based on actual production data, the cost of labor allocated to each PP sheet is **RM 0.09**. This figure reflects the direct labor cost involved in manufacturing a single unit.(Nadzri, N. R. M., 2025)

3.2.3 Material cost

$$Price\ per\ (g) \times 1\ PP\ sheet\ weigth\ (g) = Material\ cost$$

$$RM\ 0.0085 \times 235g = RM\ 2.00\ (2\ panel\ front)$$

Material cost for 1 PP sheet is RM2.00-Ringgit .1 PP sheet can produce 2 front panel seats back

3.2.4 Material waste cost

$$Average\ Material\ waste\ weight \times Price\ PP\ sheet\ per\ gram = Average\ cost\ material\ waste\ for\ 1\ month$$

$$3465g \times 0.0085 = RM29.45\ Average\ cost\ material\ waste\ for\ 1\ month$$

$$(RM29.45\ Sen \div 20) \div 1000 = RM0.001\ Sen\ Average\ cost\ material\ waste\ for\ 1\ panel\ front$$

3.2.5 Defect cost

$$Average\ defect\ in\ 1\ month \times cost\ for\ 1\ panel\ front = Defect\ cost$$

$$258 \times (RM\ 2.00 \div 2) = RM258\ Average\ Defect\ cost\ for\ 1\ month$$

$$(RM\ 258 \div 20) \div 1000 = RM\ 0.01\ sen\ average\ defect\ cost\ for\ 1\ panel\ front$$

3.2.6 Maintenance basic service cost

$$Basic\ service\ cost\ annualy\ \div 12\ months = basic\ service\ per\ month$$

$$1800\ \div 12\ months = 150$$

$$(150 \div 20) \div 1000 = RM0.0075\ Sen\ cost\ maintenance\ for\ 1\ panel\ front\ produce$$

3.2.7 Shipment cost

$$RM500 \div 20000\ unit\ of\ Panel\ front = RM0.025\ sen\ for\ 1\ Panel\ front$$

Minimizing the production cost in the manufacturing of the RU Pacifica panel front was one of the main objectives of this study. Before the implementation of the die-cut, the production cost per unit was RM2.27, driven by prolonged cycle times associated with manual die-cutting methods.

After the die-cut was introduced, the improved cutting precision and consistency reduced material waste and defects significantly, while also optimizing the cycle time. As a result, the production cost per unit decreased to RM1.16, representing an 48.89% cost reduction. This improvement has made the production process much more cost-efficient and sustainable.

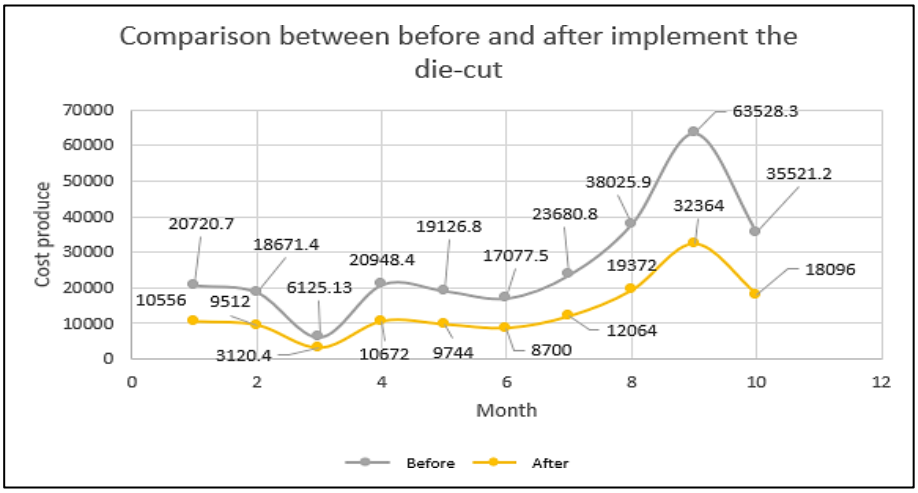


Figure 3: Cost produce per month

4.0 CONCLUSION

The implementation of an in-house die-cutting for RU panel front production has proven to be a highly effective strategy in improving operational efficiency and reducing manufacturing costs. By shifting from outsourced processes to a controlled, internal system, RU Pacifica achieved significant gains in production flexibility, lead time reduction, and overall process reliability. The initiative resulted in a 34.4% reduction in cycle time, a decrease in unit cost from RM2.27 to RM1.16 that is 48.89%. These outcomes highlight the strategic value of investing in lean manufacturing tools and underscore the potential for similar cost-effective innovations to drive sustainable growth across related production lines.

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The author would like to extend sincere thanks to RU Pacifica team for granting access to their facilities and providing essential data and support throughout the course of this study. Special appreciation goes to the production and engineering teams for their cooperation and technical input, which were crucial in the development and analysis of the die-cutting jig implementation. The author also gratefully acknowledges the guidance and mentorship of Puan Siti Atiqa Alzahra Binti Mat Darus , whose expertise and encouragement were instrumental in shaping the direction and quality of this research. Thanks are also due to Politeknik Sultan Azlan Shah for providing the academic resources and environment necessary to complete this work. Lastly, appreciation is extended to all external consultants and funding sources who supported the project, either directly or indirectly.

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Identifying Optimal Water Ratios in Diesel-Water Emulsified for Fuel Consumption Efficiency with Real-Time Emulsified Fuel Supply System (RTES)

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ABSTRACT

Diesel engines are widely used due to their efficiency, but increasing fuel costs and environmental concerns drive the need for alternative fuels. Emulsified diesel-water has shown potential to improve combustion efficiency and reduce fuel consumption by blending water with diesel fuel. This study aims to systematically measure the fuel consumption of pure diesel and diesel-water emulsified with water contents of 8%, 10%, 12%, and 15% under controlled operating conditions. Additionally, it compares the fuel consumption data to identify trends and correlations related to the water content in the emulsifieds. The experiments were conducted using a turbocharged Nissan Navara diesel engine equipped with a Real-Time Emulsified Fuel Supply System (RTES), which was implemented to dynamically prepare and deliver stable diesel-water emulsified fuel mixtures during testing. Fuel consumption was measured at engine speeds ranging from 800 to 2000 rpm using a chassis dynamometer. Each fuel blend was tested multiple times to ensure reliability. Results demonstrate that the 10% water-emulsified diesel (E10) consistently achieved the lowest fuel consumption, with savings between 7.19% and 8.33% compared to pure diesel across all tested speeds. Other emulsions also reduced fuel consumption but to a lesser extent. The RTES enhanced combustion through improved fuel atomization and micro-explosions, leading to more efficient burning. In conclusion, this study identifies E10 as the optimal water-to-diesel ratio for maximizing fuel savings, recommending the implementation of RTES in the Nissan Navara to improve engine efficiency and reduce operational costs.

Keywords: diesel-water emulsified, fuel consumption efficiency, Real-Time Emulsified Fuel Supply System (RTES).

1.0 INTRODUCTION

Diesel engines remain widely used across many industries due to their proven efficiency and reliability (Patel & Dhiman, 2022). However, rising fuel costs and growing environmental concerns have increased the demand for alternative fuels that can reduce consumption and emissions (Mohd Tamam et al., 2023). One promising alternative is diesel-water emulsified fuels, which blend water into diesel to improve combustion efficiency (Alaa et al., 2021). This innovation holds the potential to reduce fuel usage significantly while maintaining engine performance (Mahdi et al., 2024)

Despite the potential benefits, widespread industrial adoption of diesel-water emulsified fuels has been slow. A major barrier is the lack of comprehensive data on the optimal water-to-diesel ratio, especially under different engine speeds. Most existing research has concentrated on emissions reduction rather than detailed analysis of fuel consumption (Gowrishankar & Krishnasamy, 2022). Without clear, systematic evidence on fuel-saving performance, industries remain hesitant to replace conventional diesel with emulsified fuels.

Previous studies, such as those by Ramlan et al. (2020) and Abdollahi et al. (2020), have highlighted the environmental advantages of diesel-water emulsified fuels but have provided limited data on fuel efficiency across varying engine loads. Moreover, research by Abd Razak et al. (2021) and Husain et al. (2021) stresses the importance of understanding fuel consumption trends to facilitate industrial uptake. These works underscore the need for controlled experimental data evaluating how different water percentages affect diesel engine fuel consumption.

To address these gaps, this study employs a Real-Time Emulsified Fuel Supply System (RTES) to precisely prepare and deliver diesel-water emulsified fuels with 8%, 10%, 12%, and 15% water content. Using a turbocharged Nissan Navara diesel engine and a dynamometer, fuel consumption is measured across engine speeds ranging from 800 to 2000 rpm. The RTES ensures stable and consistent emulsification during operation (Abdul Rahman et al., 2025), allowing for accurate comparison between pure diesel and various emulsified fuel blends under controlled laboratory conditions.

The RTES system offers a unique advantage by enabling dynamic, real-time control of fuel composition, which leads to reliable and reproducible fuel consumption measurements. This precise mixing capability facilitates identification of the optimal water-to-diesel ratio that maximizes fuel savings without compromising engine reliability. The study's findings provide practical insights for industries seeking sustainable fuel solutions, confirming the potential of diesel-water emulsified fuels to reduce operational costs and environmental impact effectively.

2.0 EXPERIMENT DETAIL

This study evaluates the fuel consumption of diesel-water emulsifieds with water contents of 8%, 10%, 12%, and 15% using a turbocharged Nissan Navara diesel engine. The emulsifieds are prepared and delivered using a Real-Time Emulsion Fuel Supply System (RTES), which dynamically maintains a stable water-to-diesel mixture during engine operation.

2.1 Test Vehicle and Engine

The test was conducted using a turbocharged diesel-powered vehicle equipped with a standard fuel injection system. This vehicle was selected due to its compatibility with the Real-Time Emulsified Fuel Supply System (RTES) and its ability to operate reliably under varying load conditions. The engine was subjected to performance and fuel consumption tests using a chassis dynamometer, allowing precise measurement across a range of engine speeds (800 to 2000 rpm). This setup provided a controlled environment to evaluate the effects of diesel-water emulsified fuels on real-world engine behavior.

Figure 2.1: Nissan Navara

Figure 2.1 above displays the Nissan Navara, selected as the test platform for the experimental evaluation conducted in this study.

Table 2.1: Nissan Navara Specifications

Parameter	Specification
Model	Nissan Navara
Power	190 Hp @ 4000 rpm
Torque	450 Nm @ 2000 rpm
Engine location	Front, Transverse
Engine displacement	2488 cm^3
Number of cylinders	4
Position of cylinders	Inline
Cylinder Bore	89 mm
Piston Stroke	100 mm
Compression ratio	15
Number of valves	16
Fuel System	Diesel Common rail
Engine aspiration	Turbocharger, Intercooler

Table 2.1 shows the specifications of the Nissan Navara, which was used as the test vehicle in this study.

2.2 Fuel Preparation

Fuel preparation plays a critical role in this study. A single type of commercial diesel fuel, Petronas Dynamic Diesel, was exclusively used to maintain data consistency and minimize variability arising from different fuel grades. Emulsified fuels with accurately measured water-to-diesel ratios of 8%, 10%, 12%, and 15% were systematically prepared to examine their effects on combustion efficiency and engine performance under controlled experimental conditions.

Figure 2.2: Logo of Petronas Diesel Euro 5

Figure 2.2 shows the logo of Petronas Dynamic Diesel Euro 5. It is also known as Commercial Dynamic Diesel Fuel B20 and was used as the base fuel.

Table 2.2: Petronas B20 Diesel Specification

Specification	Details
Fuel Type	Diesel with 20% Biodiesel (B20)
Biodiesel Source	Palm Methyl Ester (PME)
Compliance Standard	Malaysian Standard MS 123-5:2020
Euro Standard	Euro 5
Sulfur Content	Max 10 ppm
Cetane Number	Typically ≥ 51
Flash Point	> 55°C
Density @ 15°C	Approx. 840 - 860 kg/m³
Viscosity @ 40°C	2.0–4.5 mm²/s
Cloud Point	-3°C to 13°C (depends on batch and biodiesel content)
Pour Point	-15°C to 5°C

Table 2.2 outlines the key properties and specifications of the B20 diesel fuel employed in the current study. The fuel contains 20% biodiesel derived from palm methyl ester (PME) and complies with Malaysian Standard MS 123-5:2020 and Euro 5 emission regulations. Its properties, such as low sulfur content, high cetane number, and appropriate viscosity and density, ensure consistent combustion performance and reliable results when mixed with varying water contents in the emulsified fuels tested. (Dafsari et al., 2019)

2.3 Real-Time Emulsified Fuel Supply System (RTES)

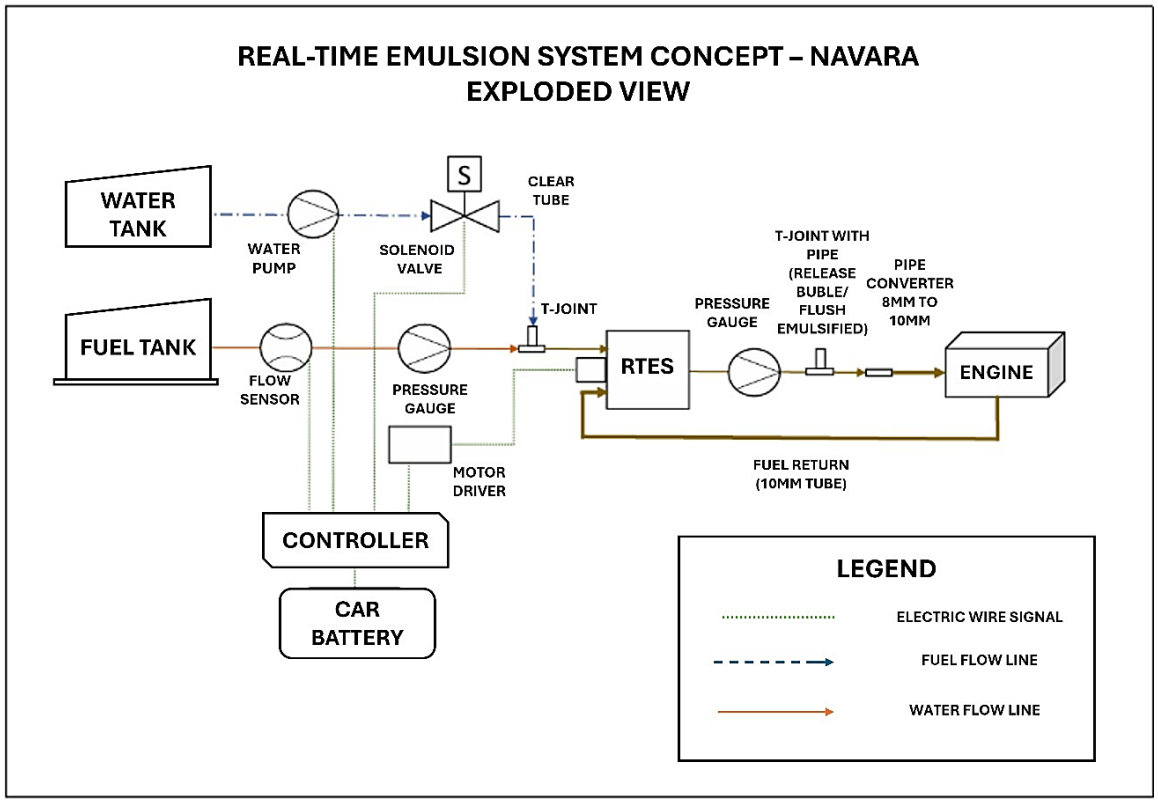

Figure 2.3: R.T.E.S System Diagram

Figure 2.3 above illustrates the RTES diagram installed at Nissan Navara. This real-time emulsified system blends water into diesel fuel to improve engine performance and reduce emissions (Ramlan et al., 2020). Water is pumped from the water tank and controlled by a solenoid valve, while diesel flows through a sensor-monitored line. Both fluids meet at a T-joint where the Real-Time Emulsified System (RTES) mixes them into a stable emulsion before delivering it to the engine. The entire process is managed by a controller receiving data from flow and pressure sensors, adjusting pumps and valves for precise water- to-diesel ratios. (Ramlan et al., 2020) A return fuel line maintains consistent pressure and flow. This setup enables dynamic control of fuel composition to optimize combustion efficiency and fuel economy in the Navara engine. (Abdul Rahman et al., 2025)

2.4 Test Procedure

A clear and consistent test procedure is crucial in experiments to ensure accurate, reliable, and repeatable results. It defines the steps for preparing samples, operating equipment, and collecting data, reducing errors and variations. This consistency allows meaningful analysis and comparison of outcomes.

In our test procedure, we prepare a diesel-water fuel mixture using a real-time emulsified fuel supply system (RTES) and test it in a Nissan Navara vehicle running on a roller dynamometer. Sensors measure fuel flow and engine performance, and all data is recorded for analysis to study how different water contents affect fuel efficiency and engine behavior.

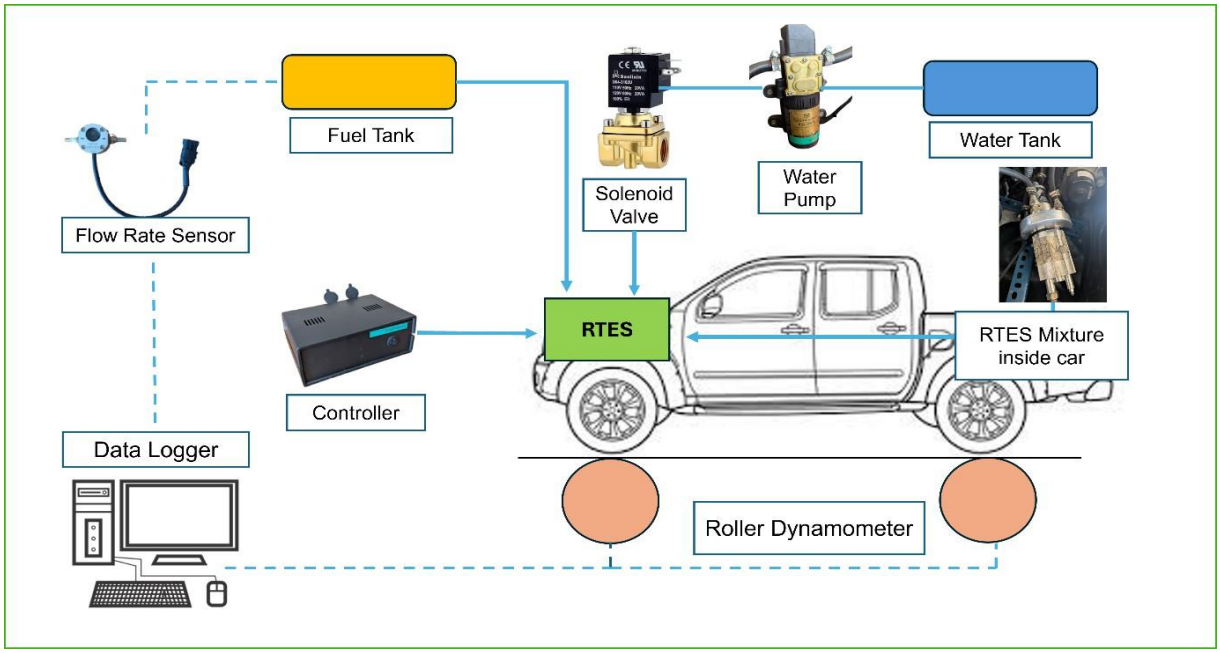

Figure 2.4: Testing Procedure for Fuel Consumption Diagram

Figure 2.4 shows a test setup using a Nissan Navara vehicle to study diesel-water emulsified fuel. Diesel from the fuel tank and water from the water tank are mixed in real-time by the RTES, which controls water flow with a pump and solenoid valve. The emulsified fuel is supplied to the Nissan Navara's engine. The vehicle runs on a roller dynamometer that simulates driving conditions. Sensors measure fuel flow and engine performance, while a data logger records all data for analysis. This setup helps evaluate how different water-to-fuel ratios affect the engine's fuel efficiency and performance.

Figure 2.5: Nissan Navara on going Fuel Consumption Test on a dynamometer machine

Figure 2.5 above shows a Nissan Navara on a chassis dynamometer for testing. The vehicle's wheels are on rollers to measure engine performance, power, and emissions under controlled conditions without driving on the road. This testing helps evaluate fuel efficiency and engine behavior accurately.

Fuel consumption was tested at five different engine speeds: 800, 1000, 1200, 1500, and 2000 rpm, simulating various industrial operating conditions. For each water content level, the emulsified fuel was prepared and delivered via RTES, and consumption data was recorded. Each test was repeated three times to ensure reliability. The laboratory environment was controlled for temperature and humidity to minimize external variability.

2.5 Data Collection

Fuel consumption was recorded using the mechanical flow sensor calibrated to pulses per milliliter. The start and end pulse counts for each test period were logged, and total fuel volume was calculated. Data was compiled into a matrix model comparing fuel types (pure diesel vs. emulsified fuels) across engine speeds.

Table 2.3: Average data for Fuel Consumption

RPM (rev/min)	Diesel (L)	E8 (L)	E10 (L)	E12 (L)	E15 (L)
800	0.0528	0.0502	0.0484	0.0494	0.0516
1000	0.0673	0.0646	0.0623	0.0632	0.0661
1200	0.0894	0.0861	0.0829	0.0847	0.0875
1500	0.1097	0.1062	0.1018	0.1039	0.1083
2000	0.1237	0.1204	0.1146	0.1176	0.1224

Table 2.3 explains average fuel consumption in liters for diesel, E8, E10, E12, and E15 at engine speeds from 800 to 2000 RPM. Data were collected from three trials per RPM, each lasting 3 minutes. The values are averages from these trials, reducing variability and providing a reliable measure of fuel consumption under different conditions.

2.6 Comparative Analysis

To assess the practical impact of using diesel-water emulsions, each blend's average fuel consumption was compared directly with pure diesel at the same engine speeds. The percentage fuel savings was calculated using the following formula:

$$Fuel\ Savings\ (\%) = \left(\frac{\text{Diesel Consumption} - \text{Emulsion Consumption}}{\text{Diesel Consumption}}\right) \times 100$$

Example Calculation for E10 at 800 RPM:

Given:
Diesel Consumption at 800RPM = 0.0528L E10 Consumption at 800RPM = 0.0484L Insert this data in the formula below:

$$Fuel\ Savings\ (\%) = \left(\frac{0.0528 - 0.0484}{0.0528}\right) \times 100$$

$$Fuel\ Savings\ (\%) \approx 8.33\%$$

Table 2.4: Fuel Savings in percentage

RPM	E8 Savings (%)	E10 Savings (%)	E12 Savings (%)	E15 Savings (%)
800	4.92%	8.33%	6.44%	2.27%
1000	4.03%	7.43%	6.06%	1.78%
1200	3.70%	7.27%	5.25%	2.13%
1500	3.19%	7.19%	5.28%	1.27%
2000	2.67%	7.34%	4.92%	1.05%

Table 2.4 presents the percentage of fuel savings achieved by each emulsified diesel-water blend (E8, E10, E12, and E15) compared to pure diesel, across five engine speeds ranging from 800 to 2000 RPM.

3.0 RESULTS AND DISCUSSION

Table 2.3 and Figure 3.1 summarize the average fuel consumption of different fuel types—pure diesel and diesel-water emulsifieds with 8%, 10%, 12%, and 15% water content—tested at various engine speeds ranging from 800 to 2000 rpm.

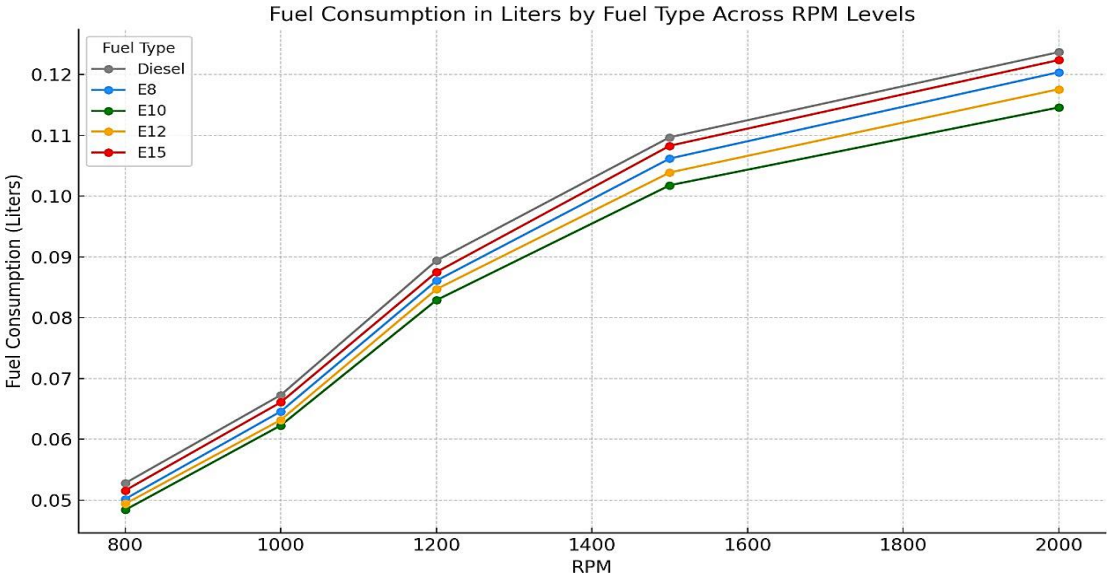

Figure 3.1: Average Fuel Consumption trends across all RPMs

The graph clearly shows that fuel consumption in liters increases steadily as the engine speed (RPM) rises from 800 to 2000 for all tested fuel types, with pure diesel consistently recording the highest consumption values across all RPM levels. Among the diesel-water emulsified fuels, E8 shows the highest fuel consumption, slightly lower than pure diesel, while E10, E12, and E15 demonstrate progressively better fuel efficiency, with E10 having the lowest consumption at every RPM point. The widening gap in fuel consumption between pure diesel and the emulsified fuels at higher RPMs suggests that the RTES is more effective at improving combustion efficiency under increased engine loads. This can be scientifically attributed to RTES's mechanism, which disperses fine water droplets into the diesel fuel, enhancing fuel atomization and promoting micro-explosions during combustion. these micro-explosions improve fuel-air mixing, reduce incomplete combustion, and lower fuel usage. Supporting this explanation, recent research (Abdul Rahman et al., 2025; Ramlan et al., 2020) confirms that water-in-diesel emulsions produced by systems like RTES can significantly reduce fuel consumption and emissions by improving combustion stability and thermal efficiency in diesel engines.

Figure 3.2 illustrates a bar chart showing that fuel savings for all emulsified fuels decrease as engine speed (RPM) increases from 800 to 2000 rpm. Among the tested blends, E10 consistently achieves the highest fuel savings compared to pure diesel across all RPM levels, followed by E12, E8, and E15. While E10 maintains relatively stable savings above 7% throughout, E15 shows the lowest performance, with savings declining to around 1% at higher engine speeds. This trend can be attributed to the effectiveness of the RTES, which enhances combustion efficiency by introducing fine water droplets into the diesel fuel. These droplets create micro-explosions that improve fuel-air mixing, resulting in more efficient and complete combustion, thereby reducing fuel consumption. This combustion enhancement mechanism is supported by studies such as (Maawa et al., 2020) (Abdul Rahman et al., 2025) which demonstrate that water-in-diesel emulsified significantly improve combustion characteristics and reduce fuel usage.

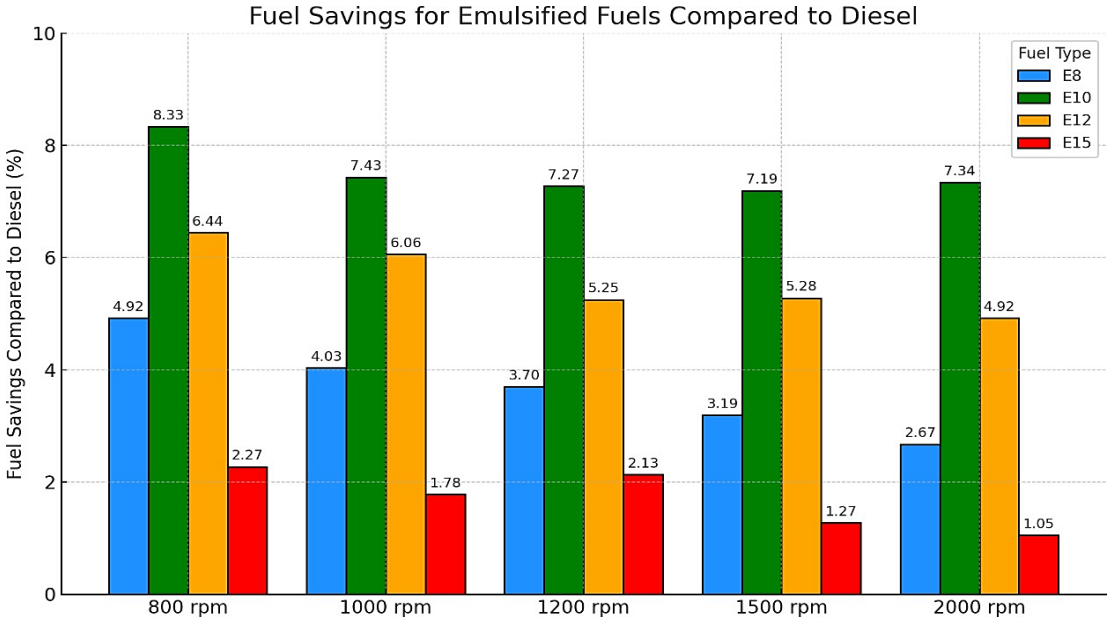

Figure 3.2: Fuel Savings for Emulsified Fuels Compared to Diesel

4.0 CONCLUSION

In conclusion, this study systematically measured and compared the fuel consumption of pure diesel and diesel-water emulsions with varying water contents, identifying 10% water content as the optimal concentration for reducing fuel consumption. Specifically, the E10 blend achieved fuel savings ranging from 7.19% to 8.33% across different engine speeds, significantly outperforming other blends. These results clearly demonstrate that the 10% water-emulsified diesel provides the most effective fuel efficiency improvement. Based on this, it is recommended to implement the Real-Time Emulsified Fuel System (RTES) using the 10% water-emulsified diesel fuel in the Nissan Navara to maximize fuel savings and operational efficiency.

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Implementation of Design and Fabricate Karakuri Kaizen to Improve Ergonomics for WIP at CO2 Robot Machine

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ABSTRACT

This thesis focuses on improving the design of a Karakuri Kaizen racking system used at the CO2 Robot Welding Machine station in Company A. The project addresses recurring defects particularly missing holes in four key components: the Block (FR Cross Member), Arm (FR Bumper LH), Plate (FR Side Member FR LH), and External FR Side Member, which are assembled with the Extension Sub-Assembly (FR Fender Apron, LH) for models D27A and D92A. These issues lead to wasted movement of Work-in-Progress (WIP) and Finished Goods (FG) poly boxes, and the manual inspection process places physical strain on operators. To solve this, the study aimed to design, develop, and test a Karakuri Kaizen mechanism that improves ergonomics and efficiency in WIP handling. The existing workstation setup was carefully analyzed to identify problems, and a new Karakuri system was designed using CATIA V5 and implemented at workstation Lot 52. This system uses simple, low-cost mechanical automation based on Lean Manufacturing principles. Testing showed a reduction in manual handling, better workflow, and improved ergonomic conditions for operators, demonstrating the effectiveness of Karakuri Kaizen in enhancing both productivity and worker well-being.

Keywords: Karakuri kaizen, Design, Lean manufacturing principle, Ergonomic

1.0 INTRODUCTION

This research aims to improve the sub-assembly process at the CO2 Robot Machine by addressing inefficiencies primarily caused by excessive worker movement. These inefficiencies arise from a disorganized storage system, which forces workers to spend significant time locating work-in-progress (WIP) materials resulting in motion waste, physical strain, and reduced productivity. Although a Karakuri racking system is currently used to simplify material handling, its effectiveness is hindered by a poorly designed layout and the absence of clear labeling. This leads to misplaced parts, cluttered workspaces, and ergonomic challenges such as awkward postures and repetitive motions, all of which increase the risk of musculoskeletal disorders (MSDs) and compromise worker safety and comfort.Karakuri is an ancient form of Japanese mechanical engineering that dates back to around 1500 years ago, when karakuri ningyo, which are mechanical dolls, were created (Christoph Roser, 2017). Karakuri is a lean technique that incorporates the use of basic mechanical devices to decrease wasted motion and enhance ergonomics in the workplace (Rob Paredes, 2023).Karakuri Kaizen's concepts align with the core principles of lean manufacturing and the Toyota Production System (TPS), which are waste reduction and continuous

improvement (Aranda Muñoz et al., 2020). By using Karakuri devices, businesses may boost productivity, save costs, and provide a safer, more pleasant work environment for employees (Alvarez & Barney, 2007).The use of lean methods is a powerful method to optimise processes and remove tasks that do not contribute value, as emphasised by (Saptari et al., 2011). Karakuri automation is always preferred, as it avoids human error and works very effectively. The authors have presented a gravity-based system for picking up WIP (work in process) poly boxes and delivering well-packed FG (finished goods) poly boxes.

1.1 PROBLEM STATEMENT

The racking system currently used for material storage is unsuitable for the production environment. It does not align with best practices for workplace efficiency or safety. Workers are required to handle poly boxes filled with parts, but the design of the racks and the lack of proper handling aids increase the risk of physical strain and injury. Repeatedly lifting or carrying these poly boxes places unnecessary stress on workers, which can lead to fatigue or musculoskeletal injuries over time. Additionally, the improper design and positioning of the racking system further slow production by creating bottlenecks in accessing materials.

Another critical issue involves the bolting process for the D92A part model. The current procedure is inefficient and prone to error due to the lack of standardized tools or proper alignment aids. Operators often struggle to secure bolts correctly, which can lead to production defects or rework, both of which are time-consuming and costly. The absence of a streamlined and ergonomic process for bolting adds to worker fatigue and reduces overall productivity.

Figure 1 Safety risks associated with carrying poly boxes

1.2 OBJECTIVES

The objective for this project is:

i. To redesign of karakuri racking for improve production layout at CO2 Robot Machine
ii. To fabricate karakuri kaizen system by optimizing the production process
iii. To analysis ergonomic issues by reducing risk factor for body posture while movement during the process

1.3 LITERATURE REVIEW

1.3.1 Karakuri Mechanism

The Karakuri mechanism functions by the utilisation of springs, gears, and other fundamental mechanisms. It intelligently utilises the law of gravity, as well as the principles of the lever, spring, cam, pulley, and other related concepts. Karakuri emphasises the utilisation of innovative applications of these basic mechanics to streamline and improve processes. The mechanism is often activated by a combination of human effort, gravity, magnetism, and elasticity, which collectively provide the force. Karakuri is an ancient form of Japanese mechanical engineering that dates back to around 1500 years ago, when karakuri ningyo, which are mechanical dolls, were created (Christoph Roser, 2017).

1.3.2 Ergonomics

Ergonomics at a factory entails the systematic examination of individuals and their working conditions, with the express aim of enhancing productivity and efficiency within the manufacturing setting. Ergonomics include the arrangement and configuration of workstations, tools, and equipment to achieve optimal compatibility between persons and their tasks, while considering factors such as physical and mental abilities, as well as the overall goals of the organisation (Rob Paredes, 2023). Ergonomics is a scientific discipline that specifically examines the interactions between individuals and different elements within a system. This profession utilises theory, concepts, data, and procedures to create systems that improve both human well-being and total system performance.

1.3.3 Musculoskeletal Disorder (MSD)

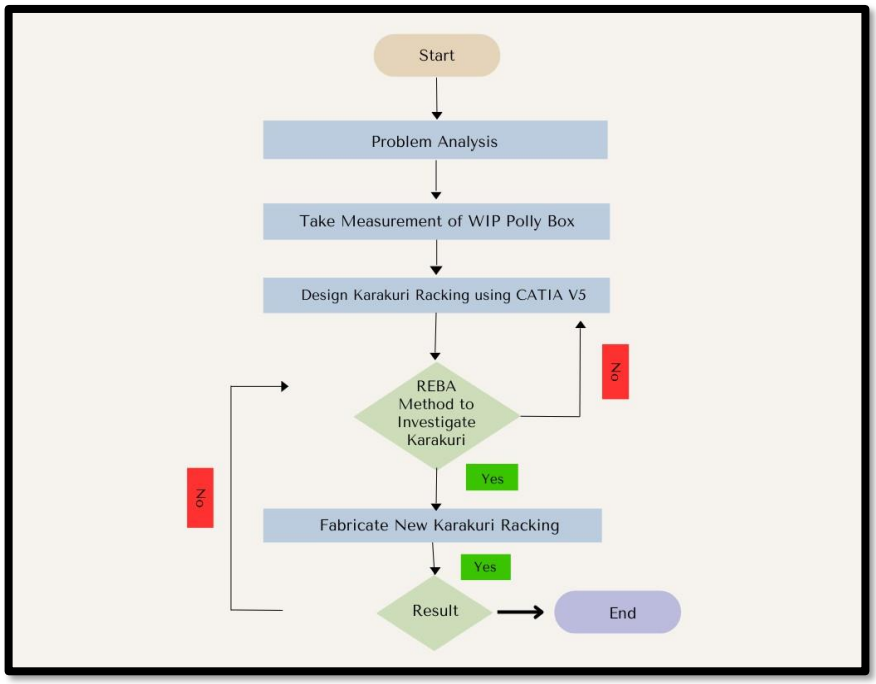
Musculoskeletal disorders (MSDs) refer to injuries or discomfort that occur in the human musculoskeletal system, which encompasses the joints, ligaments, muscles, nerves, tendons, and structures that provide support to the limbs, neck, and back (Matt Middlesworth, 2024). MSDs can occur because of abrupt physical effort, such as lifting a large object, or they can develop from repetitive acts or prolonged exposure to stress, vibration, or unpleasant positions. Typical musculoskeletal conditions include carpal tunnel syndrome, tendonitis, muscle/tendon strain, ligament sprain, tension neck syndrome, rotator cuff tendonitis, back pain, and degenerative disc degeneration. Common symptoms of this condition may include enduring discomfort, inflexible joints, inflammation, and mild aches that can impact various parts of the body such as the neck, shoulders, wrists, back, hips, legs, knees, and feet.

2.0 METHODOLOGY

A methodology refers to a structured set of techniques, processes, and procedures that are employed to accomplish project objectives. At present, the entire crew manually moves poly boxes. The posture employed for hauling poly boxes is also non-ergonomic, resulting in

problems such as back and joint discomfort. Once the problem has been identified and a thorough examination of existing literature has been conducted, data will be collected to create the design for the Karakuri Kaizen system and make informed decisions regarding its design. The project flowchart, used in this study as a process flowchart, is depicted in Figure 2 below.

Figure 2 Flow chart for the project



2.1 Identify Problem

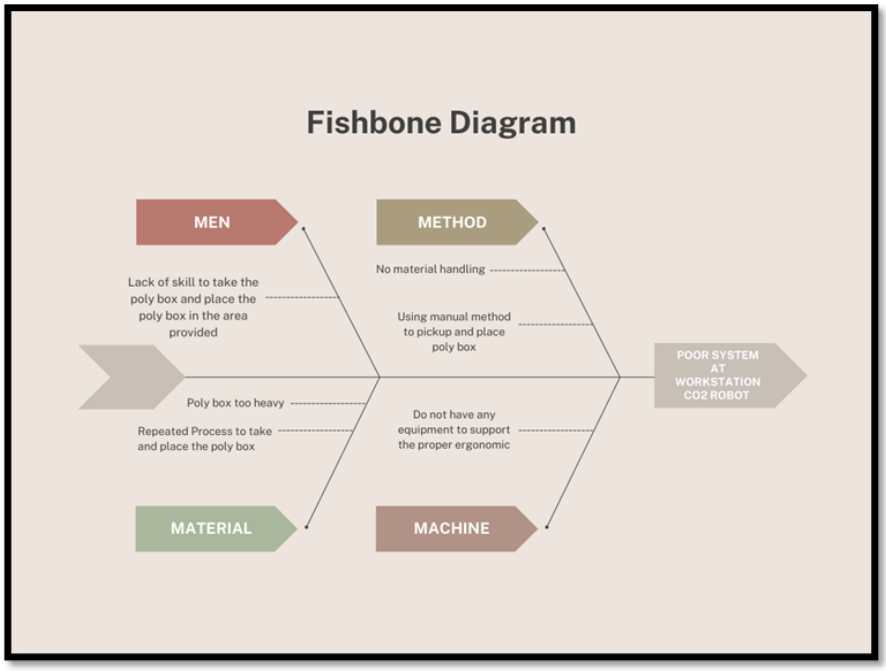


Figure 3 Ishikawa diagram

2.2 4M METHOD

Table 1 Problem by using 4M method

Category	Cause
Men	Lack of skill to take the polybox and place the polybox in the area provided
Method	Using manual method to pick up and place poly boxes
Material	Poly box is too heavy to handle
Machine	Did not have any equipment to support the proper ergonomic

According to Table 1, the reasons for the failures identified earlier have resulted inferior productivity and efficiency on the assembly line. We observe that the manual process of collecting and transferring poly boxes continues for a day. This excessively prolongs the cycle time. Therefore, we need to solve the problem using the 4M method. Observations suggest that the workstation assembly line would benefit from the implementation of the Karakuri Kaizen system as a solution.

2.3 RISK ASSESSMENT

$$\frac{\text{Sum of severity}}{\text{No of severity}} = \text{total severity} \qquad (3)$$

$$\text{Total severity x Rate of frequency} = \text{Risk Assessment}$$

The total severity of the job the employee performs determines the level of risk. Therefore, if the FG poly box is moved manually, the operator will have a high risk of back injury. According standard data criteria for risk assessment, the operator will be at high risk of back injury if the WIP polybox and FG polybox are moved manually.

2.4 RAPID ENTIRE BODY ANALYSIS (REBA)

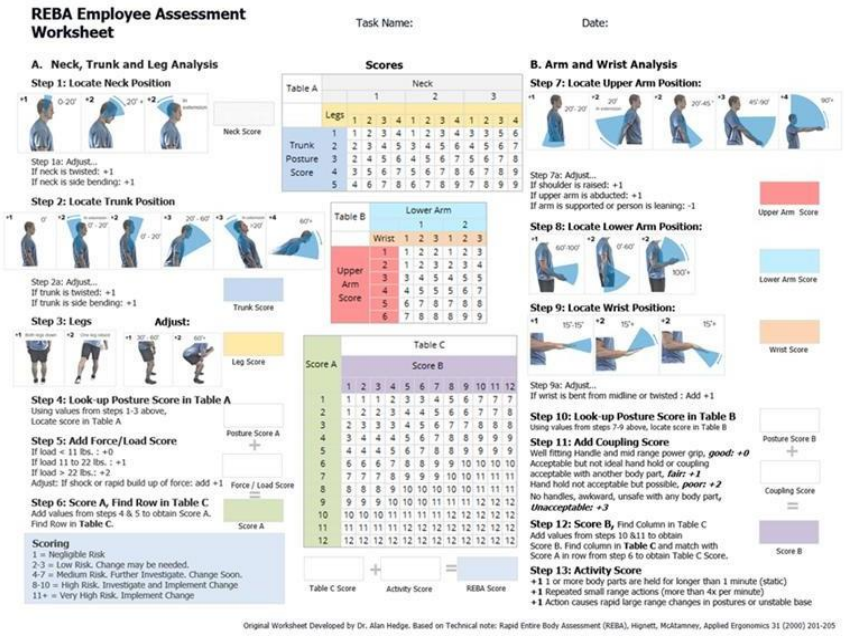


Figure 4 Rapid Entire Body Analysis (REBA)

The Rapid Entire Body Assessment (REBA) is a technique employed to evaluate the probability of developing musculoskeletal disorders (MSDs) associated with specific tasks performed in the workplace. This is a comprehensive screening tool that employs a systematic approach to assess the biomechanical and postural stresses on the entire body. The REBA is a highly adaptable and widely utilised instrument in the field of ergonomics assessments, capable of analysing the entire body and evaluating any type of job. Figure 4 illustrates the REBA approach, which involves evaluating risk factors and specific body areas for movement assessment.

2.5 SKECTHING AND 3D DESIGN

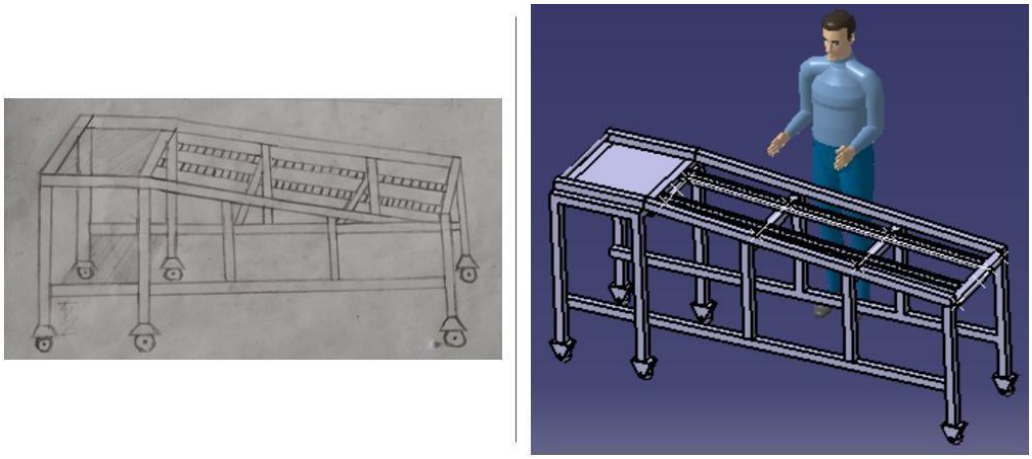


Figure 5 3D Design for Karakuri Racking while using Catia V5

3.0 RESULTS AND DISCUSSION

The results and analysis chapter discuss the data and analysis obtained from implementing the Karakuri Kaizen system at CO2 Robot Machine. Analysis is a crucial component to consider a research study successful. This research includes evaluating actual data on operator ergonomics. The experiment took four weeks to run and compute the data to generate findings and analysis for the study. Data analysis may focus on reducing ergonomic risks throughout the workday.

3.1 Rapid Entire Body Analysis (Before Vs After)

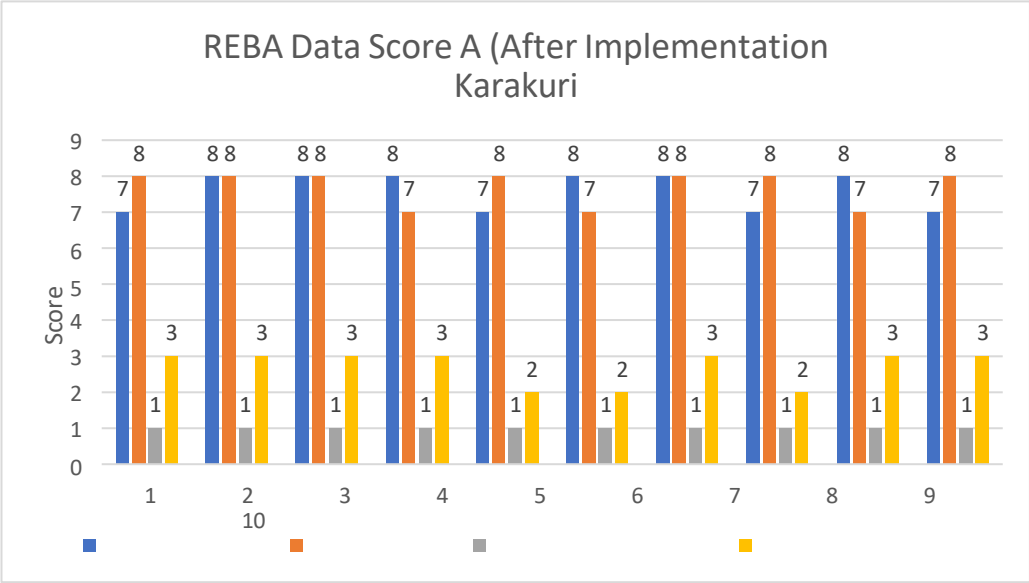


Figure 6 REBA data score A before

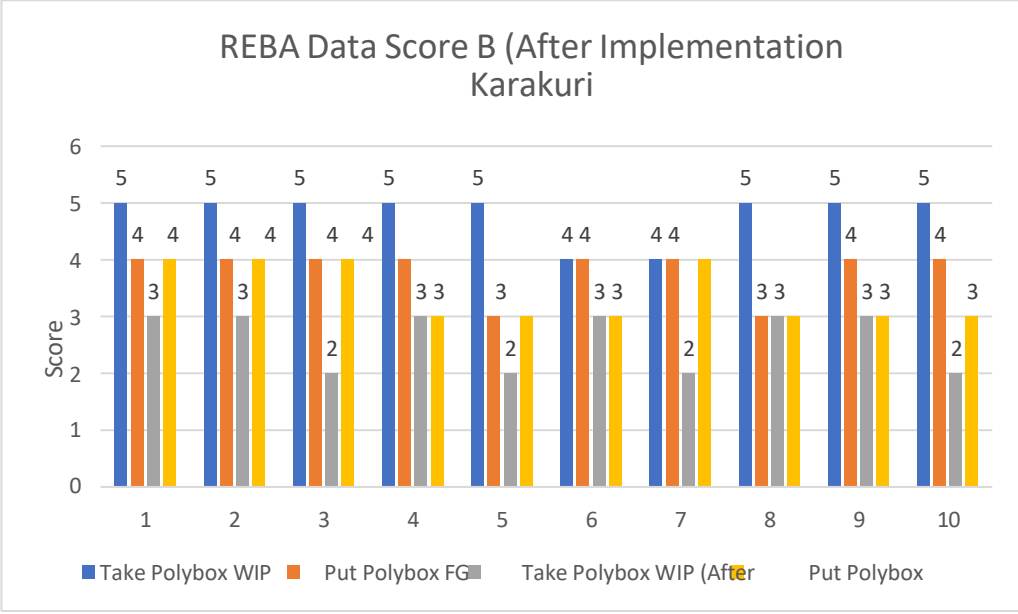


Figure 7 REBA data score B before vs after

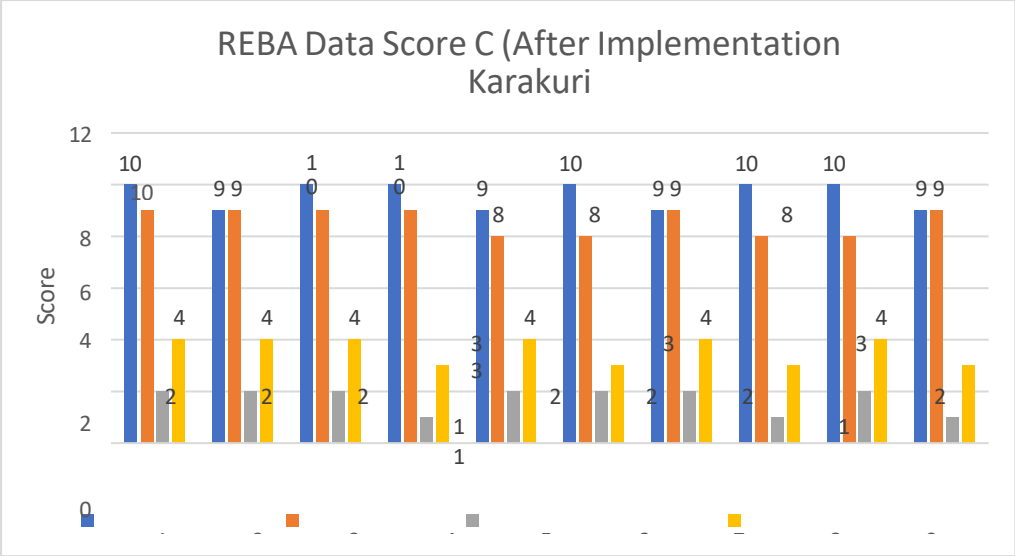


Figure 8 REBA data score C before vs after

After determining that the analysis indicated a high-risk level, changes were implemented by adding the Karakuri Kaizen system to the workstation assembly line. The Karakuri Kaizen system had a significant impact, bringing the analysis score into the safe range for the lift index. Post-implementation data for the full body analysis quickly showed an improvement in body posture. The score for fetching the WIP polybox decreased from 11 to 2, and the score for placing the FG polybox decreased from 10 to 4. The reduction in REBA scores is a result of the improved body posture following the implementation of the Karakuri Kaizen system, which supports continuous tasks.

The REBA worksheet labels the body segment components as A and B. Figure 6 illustrates that Section A (on the left side) pertains to the neck, torso, and legs. Part B (right side), as indicated in Figure 7, covers the arm and wrist. The worksheet has been separated into parts to ensure that any bending or restricted posture of the neck, trunk or legs that may affect impact the way the arms and wrists are held is included in the evaluation.

After obtaining the results of score A and B after using the implications of the Karakuri Kaizen system, score C will be shown in Figure 8, The result of score C shows a very significant decrease, which is in the process of picking up the polybox WIP decreased from 11 to 2. For the process of placing the polybox FG decreased from 10 to 4. Based on the REBA score, the process of taking the WIP polybox is at a low risk level and the process of placing the FG polybox is at a medium risk level.

4.0 CONCLUSION

Based on the results of the Rapid Entire Body Assessment (REBA), the process of taking the FG polybox scored 4, indicating a moderate risk. This score suggests that the final Karakuri design will need modifications in the future. This suggests that the final Karakuri design will need to be modified soon. Observations found that the operator had to turn his body to take the FG polybox positioned next to him. This resulted in a score of 3 for Score A and a score

of 4 for Score B in the REBA assessment. The final Karakuri Kaizen design places the FG polybox on the operator's side. This positioning causes the operator to turn his body and hands.

Therefore, design suggestions and recommendations are needed to reduce Score A and Score B in the Rapid Entire Body Assessment (REBA) results. The recommendation is to change the position of the polybox on the Karakuri from the operator's side to in front of the operator. This can reduce Score A and Score B because the operator will not need to turn their body and hands to take the polybox. The operator will only need to take the polybox from the front. Consequently, the score on the Rapid Entire Body Assessment (REBA) results could drop to 1 or 2, indicating low risk. This enhances the effectiveness and acceptability of the design.

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Improving Sludge Flow Efficiency in the Painting Line Pit

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ABSTRACT

This study focuses on improving sludge flow efficiency in the painting line pit at an automotive production facility, where sludge accumulation disrupts water flow and increases cleaning time. The objective is to enhance water movement and reduce buildup without modifying the existing pit structure. A new internal flow guide was designed and analyzed using Computational Fluid Dynamics (CFD) simulation in ANSYS Fluent, based on a 2D model with k-epsilon turbulence and measured inlet velocities. Multiple design concepts were tested, and the most effective was selected for prototyping and real-world evaluation. Simulation results showed improved flow uniformity, higher average velocity, and reduced dead zones. After implementation, the sludge volume was reduced by approximately 35-45%, and daily cleaning time decreased by 30%. These results demonstrate that a simple guide installation can effectively optimize sludge flow without structural alterations, validating CFD as a practical tool for industrial process improvement.

Keywords: Sludge flow, CFD, pit optimization, painting line, manufacturing.

1.0 INTRODUCTION

In the automotive paint sector, water is used to flow the paint overspray in sludge pits to generate a semi-solid paint sludge lumps and generates problems of excess amounts of water stable levels and equipment failures (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). Sludge production at Italian car plants is between 2.5 and 5.0 kg per vehicle, causing a number of maintenance problems. Problems become exacerbated due to poor sludge flowing, turbulence and dead areas resulting in settling of the sludge at unwanted sites. These are not very efficient for down time and operator load. It is for this reason that effective sludge management, particularly considering flow design and environmentally friendly treatment options, is crucial to limiting environmental damage and operation costs (Nair et al., 2021; Ejimofor et al., 2021; Ait Talhajt et al., 2023; Uçaroğlu & Gümrah, 2024).

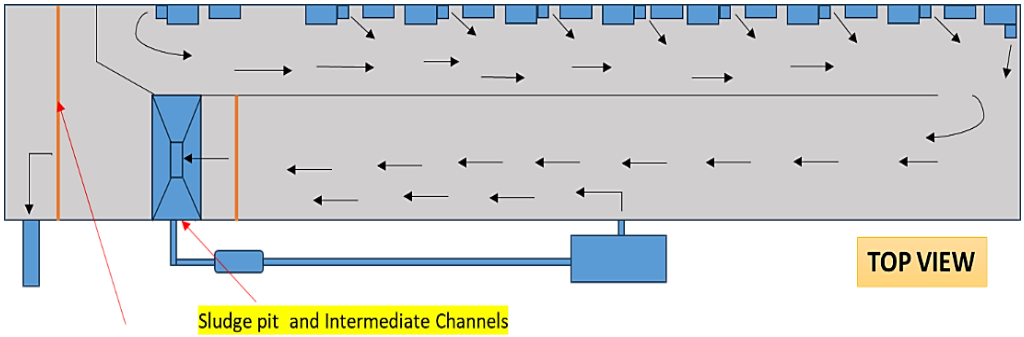


Figure 1: Top View of Sludge Pit

The figure above show the top view layout of the painting line's water circulation system, highlighting the sludge pit and intermediate channels used to transport water and accumulated sludge. Arrows indicate the flow direction of water throughout the system. After water passes through the spray booth area, it moves toward the intermediate channels, which guide it back to the sludge pit for separation and treatment.

The sludge pit, located near the central region, acts as a collection and settling point where sludge can be trapped before clean water is recycled. The flow behavior shown here reveals how proper channeling helps maintain continuous circulation, minimize stagnation zones, and ensure effective sludge transport. The system plays a critical role in maintaining filter performance, reducing downtime, and supporting sustainable water reuse in the painting process.

1.1 Problem Statement

The painting line pit has been facing continuous challenges due to the accumulation of semi-solid paint sludge that floats on the surface of the water. This sludge tends to cluster and obstruct the flow paths within the pit, particularly near the inlet and outlet (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). As a result, the water circulation becomes inefficient, leading to higher chances of filter clogging and increased frequency of maintenance (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). The pit's condition often becomes unpredictable, requiring unscheduled cleaning that disrupts the production schedule (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). Moreover, the current methods for managing sludge buildup are reactive and labor-intensive, lacking long-term effectiveness (Ruffino et al., 2023; Nair et al., 2021; Show et al. 2020). These conditions contribute to delays in production, increased workload for operators, and unnecessary maintenance costs (Ait Talhajt et al., 2023; Uçaroğlu & Gümrah, 2024). A practical and engineered solution is required to ensure the sludge can be effectively directed toward the outlet and continuously removed without interrupting the painting operation.

Figure 2: Sludge Pit at Painting Line

Figure 2 shows the actual condition of the sludge pit located beneath the painting booth in an industrial production line, where overspray paint particles mix with water and coagulants to form sludge that settles at the bottom. The pit contains several compartments intended to separate heavier sludge from circulating water; however, stagnant zones are clearly visible, indicating poor flow conditions that cause frequent clogging and require manual cleaning. The presence of accumulated paint residue and surface turbulence suggests uneven sludge movement, contributing to blockages and reduced filter efficiency. This image underscores the real-world operational issues that the project aims to resolve through improved pit design to enhance flow, minimize sludge buildup, and increase maintenance efficiency.

1.2 Objective

The objective of this study is to design and implement a sludge flow optimization mechanism in the painting line pit that improves water circulation, reduces sludge accumulation, and minimizes unplanned downtime in the painting process.

2.0 LITERATURE REVIEW

Paint sludge handling is difficult at industrial level due to its complicated properties with good amount of water, blockage in pit systems. Here, a critical review of studies carried out on the characterization of paint sludge, CFD modeling approaches, and mechanical methods of improving flow is presented. Relevant theoretical aspects of turbulence modeling and sludge rheology are also presented, with a view to facilitate the simulation.

2.1 Paint Sludge Characteristic

Paint sludge, as non-Newtonian semi-solid waste generated by industrial painting, has vasculiferous rheological characteristics depending on the nature of paint, application technique and chemical admixtures (Salihoglu & Salihoglu, 2016). It is often lighter and is bulkier than sludge sediments and therefore more difficult to settle out and clear from the water. Additives "coagulants" in technical jargon make the product more viscous, and coagulate into floating clumps that can clog filters. From a rheological perspective "paint" sludge exhibits viscoelastic gel like behavior when it encounters high yield stress which causes pumping and treatment problems (Dalmazzo et al., 2017; Dentel, 1997). Reasonably accurate rheology characterization is required in order to design efficient handling systems while this is problematic due to the variability in composition of sludge (Hii et al., 2019). Tuning the rheology of the sludges is a critical aspect toward enhancing the treatment and the reuse such as construction applications.

2.2 CFD Application for Flow Optimization in Sludge Systems

Numerical simulations/tracer studies /modeling Computational fluid dynamics (CFD) can provide a valuable support formulation solving tool to optimize sludge flow, for detailed analysis of hydrodynamics, mixing and settling in treatment tanks and pits (Karpińska & Bridgeman, 2015; Patziger, 2021). The relatively widely used k-ε turbulence model can provide a good trade-off between accuracy and computational effort, however, more advanced models such as RSM and LES may have improved accuracy at increased computational costs (Climent et al., 2018). In CFD analyses, tetrahedral or hybrid grids equipped with boundary layer refinements are greatly used in CFD analyses to predict the flow field precisely. Design modifications in accordance with CFD analysis (e.g. profiling of the inlet geometry, position of baffles) can minimizeesludge accumulation and improve discharge performance. With the majority of the research conducted in large municipal systems, little research has been devoted to small industrial paint sludge pits where flow is heavily influenced by pit size and equipment arrangement. On the whole, the utilization of CFD is still very useful to diagnose inefficiencies and support the optimization of sludge management (Xu et al., 2021; Karpińska and Bridgeman, 2017).

2.3 Mechanical and Design Solutions for Flow Enhancement

In the painting line process of operation, the treatment of sludge generally uses chemical pre-treatment, for example, the application of coagulation of aluminum and ferric chloride to reduce sludge volume (Balik et al., 2016). Although practical and economical, it is a control of chemical nature only, and does nothing to correct the problems associated with flow in the sludge pit.

By mechanical means, on the other hand, flow guiding installations in the pit which facilitate the sludge transport, as baffle plates (or slopes) are put up. This approach is suitable for plants with fixed-chemical system, or plants where accumulation of sludge on account of unstable hydrodynamics is experienced. Mechanical designs, unlike chemical approaches, are easily maintained and there is no organism exposure to continuous chemical input.

The present investigation regards sludge movement out of the pit to avoid blockages at inlets and filters, and is a simple module that fits without the need to modify the existing pit structure, rendering it suitable for industrial environments with tight time constraints. This mechanical one is an alternative rather than a substitute to the chemical one. With the CFD analysis integrated, the study presents a spatially more focused, and pro-active means to improve sludge flow.

2.4 Gaps and Contributions

Although mechanical solutions, such as baffles, sloped inlets, and flow-directing panels, have shown to be effective in promoting sludge movement and reducing plugging without the need for large capital investments, there are still several voids present in the literature. However, to date, few works have concentrated on compact or retrofit systems in the industrial sector, e.g. paint sludge pits (Pai et al., 2022). Moreover, even if such mechanical interventions can direct sludge to outlet areas and minimize hand-cleaning, further systematic analysis on the long-term effectiveness, as well as the maintenance and suitability with different sludge types are required (Zhang, Ye, & Wu, 2022; Pai et al., 2022). The present study adds to the literature by designing and validating retrofit mechanical configurations tailored to constrained pit geometries with the aid of numerical simulation and experimental verification to evaluate their efficacy in minus floating sludge production and flow conditioning. This methodology fills a gap in operational engineering solutions for on-site flow enhancement of waste industrial sludge systems, revealing new perspectives on the efficiency and operational advantages of targeted mechanical alterations (Pai et al., 2022).

3.0 METHODOLOGY

A systematic approach combining CFD simulation, mechanical design and experimental verification was adopted in this study to obtain sludge flow operation in the painting line pit without reconstruction of the existing structure. This procedure included five main steps: preliminary observations, CFD simulations, conceptuals design, prototype testing and performance demonstration.

ANSYS fluent was employed to simulate water flow and map turbulence and stagnation regions based on 2D steady state model. Water was assumed to be a non-Newtonian semi- solid with sludge treated in simplified manner. The k-epsilon turbulence model was chosen for its balance between accuracy and computational cost and mesh refinement and convergence checks were made.

Designs were developed in CATIA V5 using modular flow-guidance provisions. A down-scaled experimental model was designed to observe the flow and compare it with the simulation. Although precise dynamic similarity was not achieved, the model provided good qualitative information on the movement of sludge.

This approach, which combined practical observation with simulation insights, helped ensure that design decisions were grounded in real conditions, making them more realistic and easier to implement in practice.

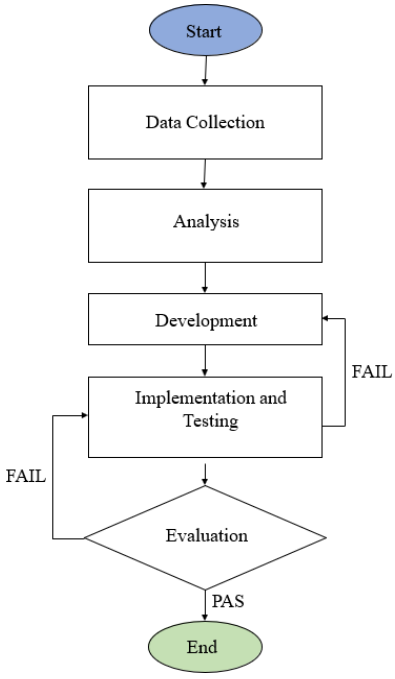


Figure 3: Project Methodology Flowchart

Figure 3 shows the overall project methodology applied in this study, starting from data collection and root cause analysis, to CFD simulation, design development, implementation, and evaluation (Ahmed, Skerman, & Batstone, 2022). This structured flow ensures a systematic approach to identify the causes of sludge accumulation and validate proposed improvements.

3.1 Data Collection and Root Cause Analysis

The sludge volume and time of cleaning of the painting line pit were measured over two weeks. The sludge volume was based on standard industrial practice which was to count the number of 20 kg buckets that the chamber was filled per shift, and the time required to perform the cleaning of the chamber was recorded as a stop-watch monitoring time. While these two methods are practical, they are also influenced by the operator interference and the sludge density, which may cause the measurement error (Chang et al., 2023). The average sludge volume was between 240 and 500 kg/day and the cleaning time was between 120 and 170 minutes per shift. Performance was assessed using standard statistics (mean, range, SD).

New technologies are now available, ultrasonic sensors and real-time concentration meters, resulting in more accurate and continuous monitoring, which may improve the quality of data in future studies (Piao et al., 2022; Hong et al., 2021).

After performing 5 Whys, it was found that flawed internal flow, due to both poor guidance structure and lack of guidance structure, was the root cause of sludge and cleaning time. This is consistent with studies that suggest poor hydraulic design as a cause of clogging/sludge accumulation (Pedescoll et al., 2011; Langergraber et al., 2003). Hence, CFD was applied to predict the characteristics of flow patterns for the design such corrective measures, which would

provide a more efficient and sustainable sludge management (Han et al., 2021; Liu et al., 2022).

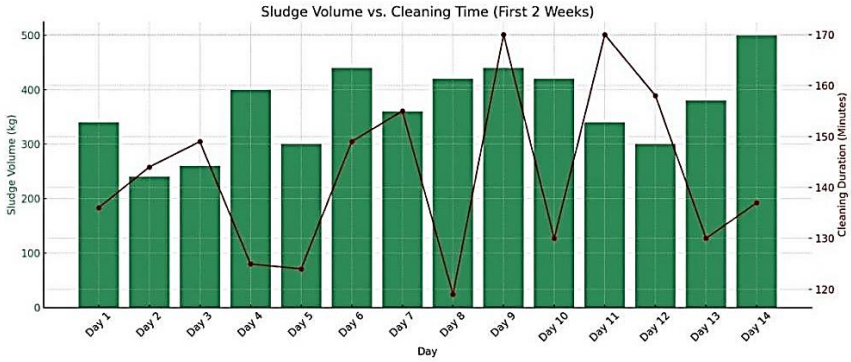


Figure 4: Sludge Volume vs. Cleaning Time (First 2 Weeks)

Figure 4 show the relationship between daily sludge volume (kg) and cleaning duration (minutes) over first 14 days in the painting line pit (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). The total sludge (volume) removed each day is illustrated by the green bars, and time spent cleaning the pit by the red line.

From the study, an average sludge volume of between 250 kg and 500 kg per day could be noted on the graph, with Day 14 being the highest of these. The length of time it takes to clean seems to depend largely on the amount of sludge which has accumulated, the more there is to remove, the longer it takes to clean. But anomalies exist like Day 8 when cleaning time decreased disproportionately although sludge volume was still high and Day 9, when sludge volume and cleaning time raised dramatically. Variations in these ranges indicate that factors other than the quantity of sludge (e.g., sludge consistency, the speed of the worker, or the condition of the filter) influence the cleaning time.

By emphasizing the operational costs of sludge that does not behave in a consistent manner, the figure similarly emphasizes the benefits of flow reaction, flow optimization, etc. in terms of reducing daily maintenance time, as well as improving predictability of pit cleanings.

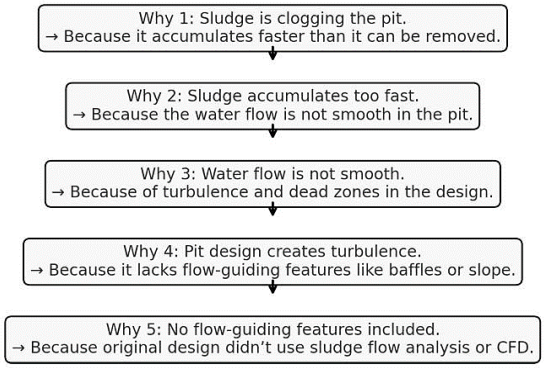


Figure 5: 5 Whys Root Cause Analysis for Sludge Clogging

Figure 5 shows is a sample of a 5 Whys for root cause analysis on sludge build up in the painting line pit. "The evidence establishes (that sludge) plugs the pit rather than going out the pit as fast as it comes in, because the water drains so poorly." This flow problem arises from turbulence and stagnant areas that are produced due to the absence of flow guiding structures, such as baffles or slopes. Finally, the issue is an original pit design, where there is noflow analysis or CFD. This result supported the adoption of new approach shaped by fluid characteristic.

Table 1: Summary of CFD Simulation Setup

Parameter	Description
Geometry Source	2D model imported from Ansys Space Claim
Fluid Domain	Water flow in painting pit
Material	Water (ρ = 998.2 kg/m³, μ = 0.001003 Pa·s)
Flow Type	Incompressible, steady-state
Turbulence Model	Standard k-ε (k-epsilon) model
Inlet Boundary Conditions	Inlet: –0.3 m/s; Inlets 1–4: –0.5 m/s
Outlet Boundary Condition	Pressure outlet (0 Pa gauge pressure)
Wall Condition	No-slip condition
Mesh Type	Tetrahedral mesh with refinement at pit floor and inlet areas
Mesh Element Size	10.0 mm (uniform size applied across fluid domain)
Solver Type	Pressure-based solver
Discretization Schemes	Second-order upwind for momentum and turbulence equations
Convergence Criteria	Residuals < 10^{-4} for continuity and momentum; < 10^{-3} for turbulence parameters
Simulation Software	ANSYS Fluent 2023 R1
Post-Processing Tools	Velocity vectors, streamlines, pathlines, and Turbulence Kinetic Energy (TKE)

Table 1 provides a concise summary of the CFD simulation setup used to study sludge accumulation in ANSYS Fluent, detailing key aspects such as model assumptions, boundary conditions, mesh configuration, and solver settings. Selecting appropriate model assumptions such as the treatment of sludge as a multiphase flow or the use of kinetic theory for granular materials ensures that the simulation accurately reflects real-world sludge behavior (Jamaleddine & Ray, 2011). Boundary conditions are typically defined to replicate actual inlet and outlet flows, wall interactions, and operational parameters, which are crucial for predicting flow paths and identifying zones prone to sludge buildup. Mesh configuration is chosen to balance computational efficiency and solution accuracy, with finer meshes applied in regions where detailed flow or particle behavior is critica. Solver settings, including turbulence models and numerical schemes, are selected based on the complexity of the flow and the need for stable, convergent solutions. Sensitivity analyses are often performed to assess the impact of mesh size and solver parameters on simulation outcomes, ensuring reliable predictions. This careful configuration allows for effective identification of sludge accumulation zones and supports the development of targeted engineering solutions.

3.2 CFD Simulation and Modeling Assumption

A two-dimensional (2D) CFD model was developed using ANSYS Fluent to simulate the steady-state water flow inside the sludge pit. Although industrial paint sludge behaves as a non-Newtonian, viscoelastic fluid with high yield stress (as described in Section 2.1), the simulation assumed Newtonian fluid behavior for simplification. This approach was adopted to reduce computational complexity during early-stage flow diagnostics and identify major flow disturbances. The standard k-epsilon (k-ε) turbulence model was selected due to its balance between accuracy and computational cost, especially in systems with turbulent recirculation

(Karpinska & Bridgeman, 2016; Manenti et al., 2018; Weiss et al., 2007). Mesh independence was confirmed by comparing results using three mesh sizes (10 mm, 7 mm, and 5 mm), with less than 5% variation between the two finer meshes. Based on this, a 7 mm mesh was used for the final simulation.

The control domain was based on the actual dimensions of the sludge pit system, using a geometry created in ANSYS SpaceClaim. Inlet boundary conditions were derived from float test measurements and factory records: one inlet at –0.3 m/s and four secondary inlets at –0.5 m/s. The outlet was modeled as a pressure outlet set to 0 Pa gauge pressure. All wall surfaces were assigned a no-slip boundary condition to reflect realistic surface friction. Table 1 summarizes the full CFD simulation setup, including geometry sources, flow assumptions, turbulence model, boundary conditions, and solver settings. This configuration ensures that the model is representative of the real system while remaining computationally practical. The approach allows for identification of dead zones, flow stagnation, and turbulent regions, serving as a foundation for optimizing the sludge flow system.

3.3 Design Selection Method

In order to decide on the best design in terms of enhancing the sludge flow, three options were formulated through application of a structured simulation-driven methodology. Each design integrated characteristics such as tapered baffles and guide panels, and were designed in ANSYS SpaceClaim while its flow response was examined in ANSYS Fluent bringing in pathline visualization for verifying flow coherence and flow streamlines and turbulence finding. This process was followed by the Pugh Matrix, where each of the designs was scored for 5 criteria, flow uniformity, turbulence reduction, streamline consistency, ease of fabrication and ease of maintenance, relative to a base line, from –3 to +3 to keep final decision between the data from simulations and the feasibility of implementation. This Multi-Criteria Decision Analysis (MCDA) process is in line with recommended practices for engineering design selection wherein structured tools such as the Pugh Matrix or the Analytical Hierarchy Process are used to avoid subjective bias and effectively compare alternatives (Nožina, Đurđević, & Trstenjak, 2020; Hreiz, Latifi, & Roche, 2015). The inclusion of CFD results in the appraisal process is consistent with recent developments in wastewater and sludge system design in which simulation data is more commonly used to underpin and corroborate design decisions (Karpinska & Bridgeman, 2016). By using quantitative model simulation results along with practical matters, this method helps to achieve reliable and transparent selection for the best available sludge flow improvement concept. (Nožina, Đurđević, & Trstenjak, 2020; Karpinska & Bridgeman, 2016) Utilization of blending calculations within the scope of modeling is also possible.

Figure 6 show illustrates three different conceptual designs proposed to improve sludge flow within the pit system, where each colored section represents a unique design feature tested to reduce sludge accumulation and enhance water movement. The accompanying table 2 provides a structured, comparative evaluation using a scoring method that minimizes subjective preferences. By summing the total scores across key performance criteria, the design with the highest overall score is objectively identified as the most suitable option for implementation.

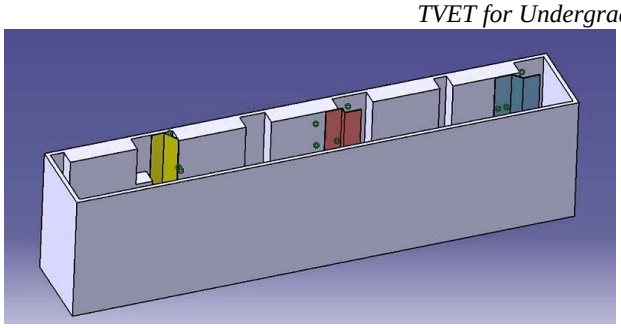


Figure 6: 3 Conceptual designs

Table 2: Scoring Scale for the design selection

Score	Explanation
+3	Much better
+2	Better
+1	Slightly better
0	Same
-1	Slightly worse
-2	Worse
-3	Much worse

3.4 Implementation and Testing

Following simulation and analytics, the chosen design, Center Channel Guide, was set up for realization in the outside world. The idea has been implemented as a first physical prototype of stainless steel because of its robustness and water resistancy. Fabrication was based on the parameters used to model CAD drawings, so that the dimensions of the box were compatible with those of the original sludge pit. The prototype was then deployed during a maintenance window in order not to disturb production. The system was tested after installation with normal usage being employed to assess the ability of the system to direct water and to prevent sludge from concentrating. The observations concentrated on flow direction, water level sustainability, and sludge movement to confirm the functioning of the design in an industrial production situation.

Table 3: Fabrication Process

Process	Description	Tools/ Equipment Used
Cutting	Stainless steel sheet cut according to CATIA drawing dimensions	CNC Laser Cutting Machine
Bending/ Forming	Guide shape formed to precise angle for pit installation	Hydraulic Press Brake
Welding	Assembly of parts using precise joints for durability and corrosion resistance	TIG Welding Machine
Surface Finishing	Sharp edges ground, and protective coating applied for long-term use	Grinder, Anti-Corrosion Coating
Pre-Assembly Check	Final check for dimension accuracy and test fit before delivery	Vernier Caliper, Manual Inspection

Table 3 show the step-by-step fabrication process used to manufacture the Center Channel Guide prototype. The process begins with cutting stainless steel sheets according to precise

dimensions generated from CAD models, using a CNC laser cutting machine for accuracy. Next, the bending/forming process is performed using a hydraulic press brake to shape the guide to its required angle for fitting inside the sludge pit. This is followed by welding, where the shaped components are joined using TIG welding, chosen for its strength and resistance to corrosion critical for wet and chemically active environments. After assembly, surface finishing is carried out by grinding sharp edges and applying anti-corrosion coatings to enhance durability and safety. Finally, a pre-assembly check is conducted to verify dimensional accuracy and ensure a proper fit prior to delivery and installation. This fabrication process ensures that the prototype meets both design specifications and real-world functional requirements.

3.5 Evaluation

The effectiveness of the Center Channel Guide design was field tested in a before/after comparison on the basis of two practical cliché, the volume of sludg e/shift (counted by bucket manually) and the time for pit cleaning (timing by stop watch). Although this technique was shown not to be optimal, this method corresponds to the common practice in industry to evaluate efficiency and effort measured by a readily available quantity (Flores-Alsina et al. 2021; Rajaei and Nazif 2022). The objectivity and comparability of the evaluation were ensured through consistent measurement methods and operating conditions, as both are mutually dependent. However, further standardization is necessary to improve the accuracy of analyzing the effects of design modifications (Flores-Alsina et al., 2021; Rajaei & Nazif, 2022). Such before-and-after comparisons are a common tool in wastewater and sludge management for evaluating process enhancements when sophisticated instrumentation is not available (Flores-Alsina et al. 2021; Rajaei and Nazif 2022). Although more advanced measures (such as effluent quality, hydraulic flow characteristics or sludge dewaterability) might provide more detailed information, the selected indicators are well suited for operational decision support and preventative maintenance algorithms (Flores-Alsina et al. 2021; Rajaei, M., & Nazif, S. 2022). This process illustrates a direct, pragmatic evaluation of whether the design change resulted in a practical improvement of sludge flow and reduction in maintenance task burden, which is essential for decisions about plant upgrades and retrofits for current and future plant equipment (Flores-Alsina et al. 2021; Rajaei and Nazif 2022; Rajaei, M., & Nazif, S. 2022).

4.0 Evaluation

The interpretation of the results of the data collection, CFD simulation and conceptual design review of modifications for enhancement of the sludge flow in the painting line pit is described in this chapter. The analysis considers the performance of the present system, the local location of sludge deposition, and the workability of suggested design changes in terms of qualitative and quantitative data (e.g., velocity profiles, turbulence patterns, sludge volume, and cleaning time).

The first part is devoted to CFD simulation of the base case with existing pit and exposes flow problems (dead zones and turbulence) through velocity contours, TKE distribution and pathline maps. The findings were used in the formulation of three different design concepts, which were numerically simulated in ANSYS Fluent, in order to evaluate the enhancements in flow uniformity and also in sludge transference.

To obtain an unbiased design choice, a Pugh matrix was also used to compare the designs in the following factors: improvement in flow, reduction in turbulence, ease in maintaining and control availability, structural control, and ease of installation. The highest scored design was chosen for manufacturing.

The comparison of performance before and after the upgrade is discussed; this comparison is carried out with the help of field data concerning the sludge volume and cleaning duration. These enhancements confirm the practical effectiveness of the design and provide suggestions for further improvements.

4.1 Design Concept Evaluation and Selection

The optimal design for increasing the efficiency of sludge flow in the painting line pit was selected based on a design analysis consisting of concept generation, CFD analysis, and scoring criteria in the Pugh matrix process. Three initial designs, with varying numbers of angled panels and channels, were designed in ANSYS SpaceClaim to counteract sludge accumulation by optimizing water pathlines and reducing turbulence. The fluid simulations of each model were performed using ANSYS Fluent code, from which velocity contours, turbulence kinetic energy (TKE) distributions and pathline patterns were investigated. Between the alternatives, the Theme 1 (Blue) showed the smoother streamline pattern in flow, reduced turbulence close to the walls located in the inlet region, the flow is alleviated at the entrance of the desludger and the corners that accumulate sludge and with less recirculation. A Pugh matrix was used to compare five criteria how the devices affect flow improvement/turbulence reduction, their fabrication, processing, and their compatibility to the existing pit on a –3 to +3 scale with a benchmark value. Concept 1 received the highest total score at all points of evaluation, particularly in the areas of hydraulic performance and ease of integration, which justified the decision to select it for prototyping and further validation. This approach is firmly rooted in engineering design best practice where CFD modelling is employed to diagnose and optimise flow behaviour, and structured decision tools such as the Pugh Matrix ensure that the most promising solution is selected in a transparent and data-driven manner (Das et al., 2015; Climent et al., 2018; Manenti et al., 2018).

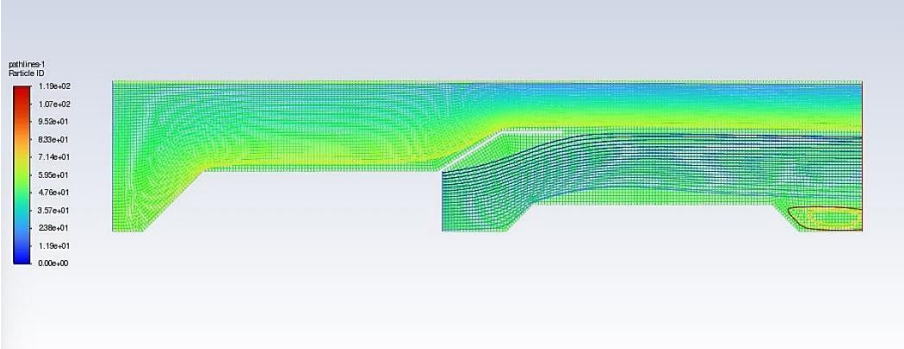


Figure 8: Simulation Design 1

Figure 8 shows smoother and more uniform streamline flow across the entire channel. The flow is well-directed toward the outlet with minimal swirling and disturbance in the pit area. This indicates better sludge transport and less accumulation. The design helps reduce dead zones, which can be seen in the more evenly spaced streamlines. This design is the most efficient based on the flow path.

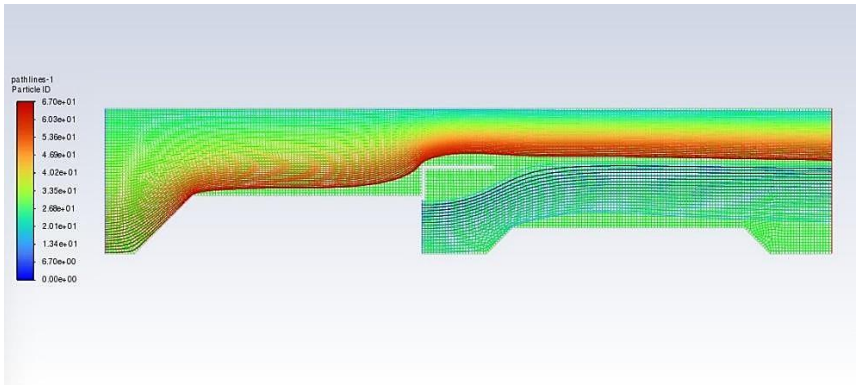


Figure 9: Simulation Design 2

Figure 9 shows the streamline pattern in this design reveals higher turbulence levels, especially near the inlet and along the upper section of the channel. Irregular flow paths and visible disturbances in the middle region suggest potential dead zones where sludge may accumulate. Compared to Concept 1, the streamlines in this design are less uniform and more chaotic, indicating weaker control over flow direction. This lack of coherent flow reduces the system's ability to direct sludge efficiently toward the outlet, making the design less effective in minimizing sludge buildup.

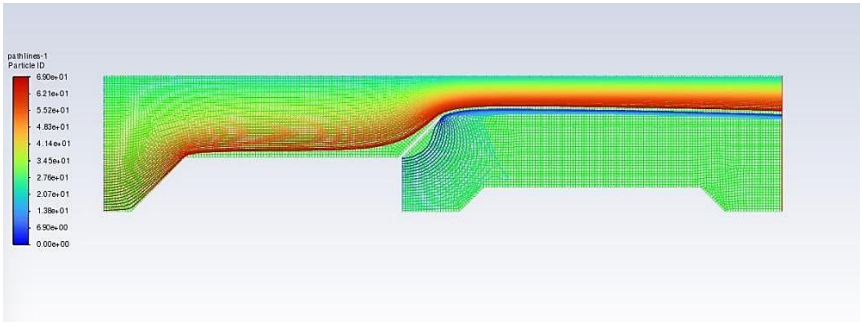
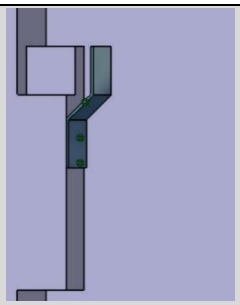
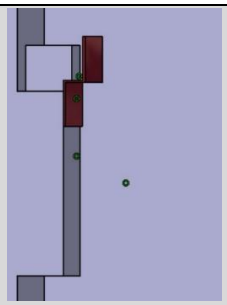
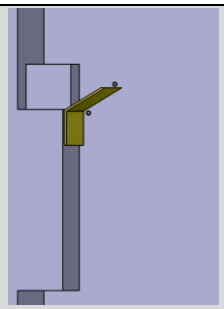


Figure 10: Simulation Design 3

This figure shows clear separation and swirling near the outlet area. Although the entry flow looks smooth, the pit region has concentrated vortex patterns. The flow is not well-aligned, and there is a risk of sludge accumulating due to the dead zone formation at the corners. It performs worse than Concepts 1 and 2 in terms of guiding sludge efficiently.

This table 3 show the comparison of three alternative designs Concept A, Concept B, and Concept C for enhancing sludge flow in the pit system. The designs were evaluated based on five criteria: flow improvement, turbulence reduction, ease of maintenance, ease of fabrication, and ease of installation. Concept A achieved the highest score with a total of 13 points, indicating the best overall performance. Concept B and C both scored 9 points, reflecting weaker performance, particularly in flow control and turbulence management. Based on these results, Concept A was selected for prototype development and further testing.

Table 4: Concept Design for Sludge Management Improvements

Criteria	 Concept A	 Concept B	 Concept C
Flow Direction Efficiency	+2	-1	+1
Turbulence Reduction	+2	+1	-1
Ease of Maintenance	+3	+3	+3
Ease of Fabrication	+3	+3	+3
Ease of Install & Remove	+3	+3	+3
Total	13	9	9
Continue	**YES**	**NO**	**NO**

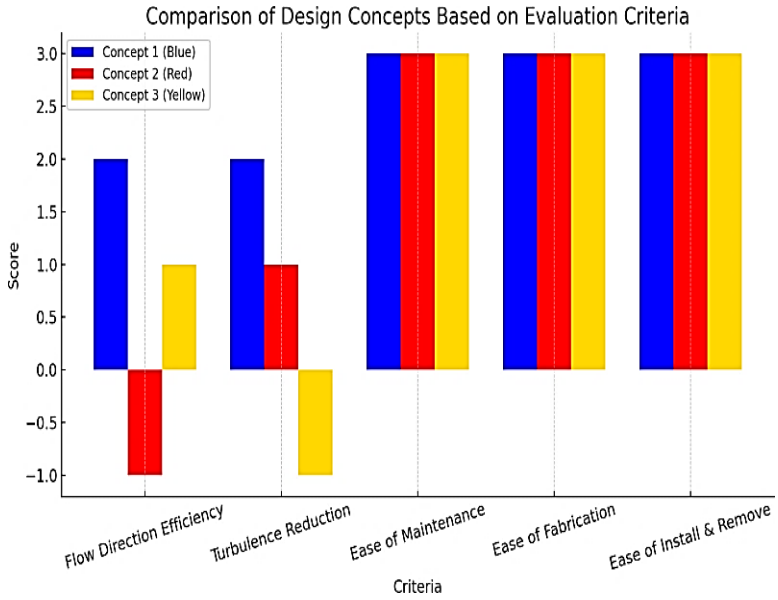


Figure 11: The three design concepts based on CFD pathline analysis

This figure gives a graphic comparing the three design concepts on five criteria. Concept 1 (Blue) had the highest values for flow direction and turbulence reduction, the important categories for enhancing the movement of the sludge. All three designs were rated the same in terms of maintenance, manufacturability and installation. Only that Concept 1 gave slightly better results, and it was introduced into practice.

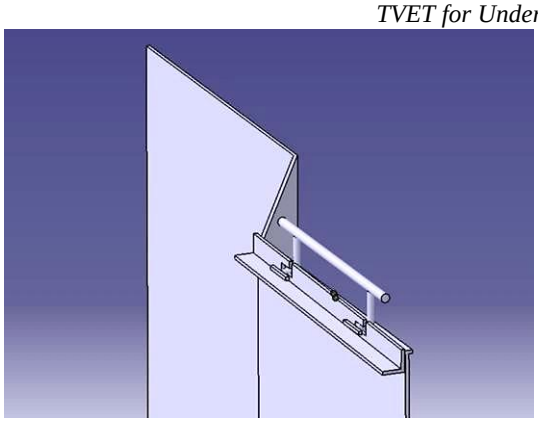


Figure 12: Final design development

Figure 12 shows the final design of the selected sludge flow improvement concept. The design includes a central guiding panel and supporting structure to direct water and sludge toward the desludger. The angled surface helps reduce turbulence and prevents sludge from settling in dead zones, while the top-mounted bar ensures structural support and ease of installation within the existing pit layout.

4.2 CFD Simulation Results and Interpretation

The CFD simulation results showed notable improvements in sludge pit flow behavior following the design modification. The average flow velocity increased from 1.50 ± 0.07 m/s to 2.20 ± 0.05 m/s, while the peak Turbulence Kinetic Energy (TKE) was reduced from 0.4017 to 0.3519 m^2/s^2. TKE was selected as a key performance indicator because it reflects the intensity of turbulence in the system; lower TKE values correspond to smoother and more stable flow, which reduces the likelihood of sludge accumulation (Wei et al., 2020; Manenti et al., 2018). Additionally, the flow uniformity index increased from 0.60 to 0.85, and the dead zone area within the pit decreased significantly from 35% to 18%, indicating enhanced flow coverage and improved sludge transport. A clear reduction in swirling and vortex formation, particularly near the inlet and outlet corners, confirmed that the new design successfully minimized chaotic flow and redirected water more uniformly across the pit. These findings are consistent with previous studies that demonstrated the benefits of introducing guiding structures to reduce turbulence and improve sludge flow performance in wastewater systems (Patziger, 2021; Weiss et al., 2007).

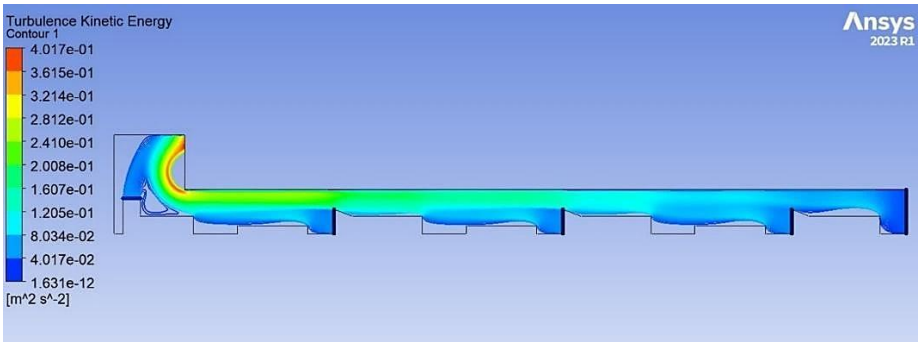


Figure 13: Turbulence kinetic energy (TKE) distribution before the pit improvement

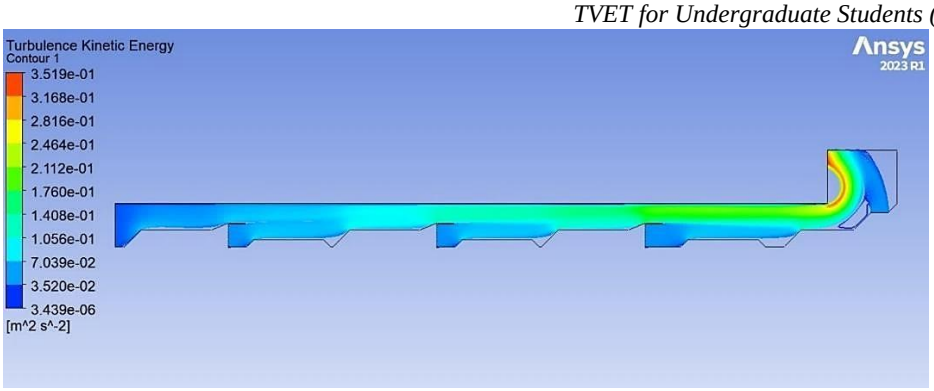


Figure 14: Turbulence kinetic energy (TKE) distribution after the pit improvement

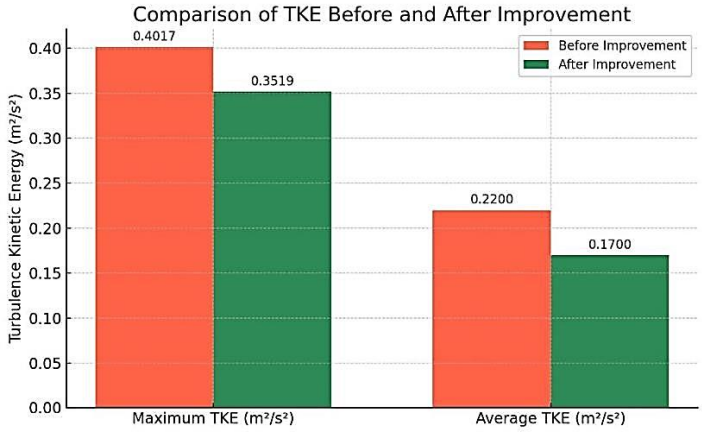


Figure 15: Comparison of Turbulence Kinetic Energy (TKE) before and after

The bar chart shows the comparison of Turbulence Kinetic Energy (TKE) before and after the improvement in the sludge pit system. The maximum TKE decreased from 0.4017 m^2/s^2 to 0.3519 m^2/s^2, indicating a reduction in peak turbulence. Additionally, the average TKE dropped from 0.2200 m^2/s^2 to 0.1700 m^2/s^2, showing that the overall flow became smoother and more stable. This confirms that the improved design successfully reduced turbulence, which helps prevent sludge buildup and improves flow movement in the pit.

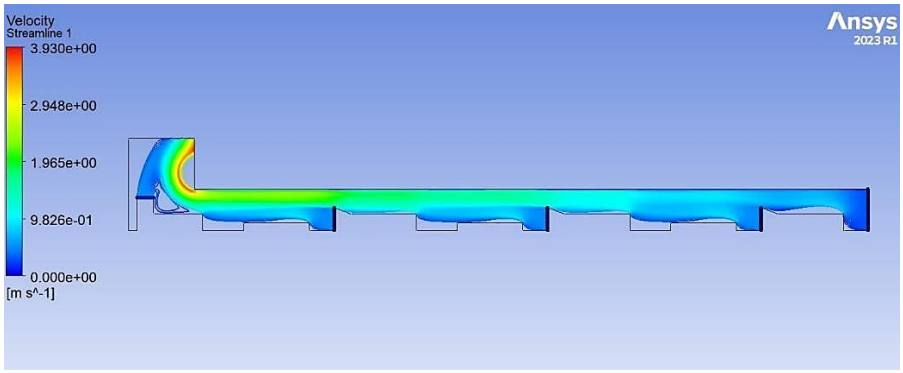


Figure 16: Velocity streamline distribution before the pit improvement

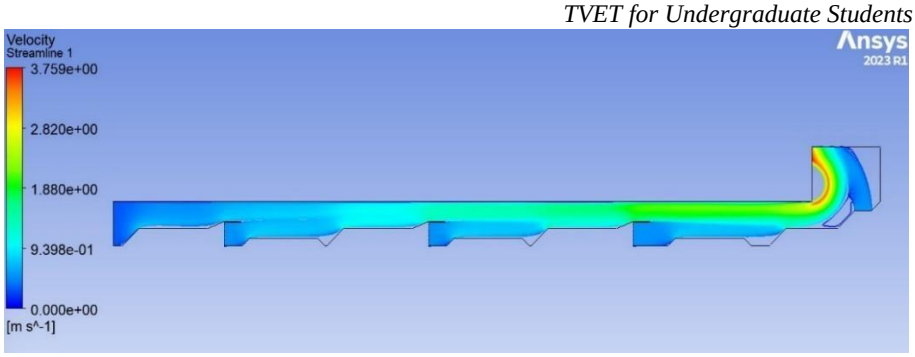


Figure 17: Velocity streamline distribution After the pit improvement

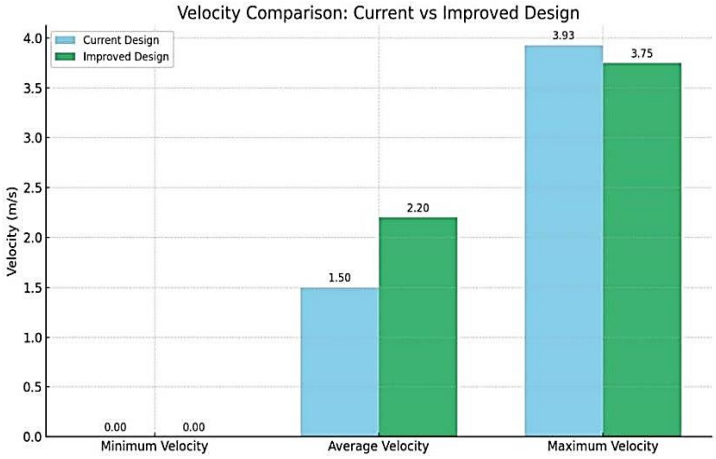


Figure 18: Velocity streamline comparison between the current and improved sludge pit designs

Figure 18 shows a velocity comparison between the current and improved sludge pit designs. In the improved design, the average velocity increased significantly from 1.50 m/s to 2.20 m/s, indicating enhanced overall water movement. This improvement suggests better sludge transport and fewer stagnant zones. Although the maximum velocity slightly decreased from 3.93 m/s to 3.75 m/s, it reflects a more uniform flow, reducing the potential for turbulence and flow surges. Both designs maintain a minimum velocity of 0.00 m/s, which likely corresponds to corner or dead zones, but overall, the improved design shows a more efficient and controlled water flow throughout the pit system.

4.3 Link Between Prototype and Flow Behavior

Flow enhancements predicted by CFD simulations were confirmed in situ by successful installation and operation of the stainless steel prototype, clearly making the connection between simulated and observed flow. Visual observations and operator feedback revealed that particulates accumulated in the vicinity of the desludger and that overall flow was smoother with fewer blockages a pattern consistent with the simulated pathlines, which also depicted that flow patterns converged and eddies were diminished in that part of the unit. This real-world validation confirms that geometricaul interventions, such as flow guides or baffles, might be successful in re-directing the flow and controlling the vortex formation which is one of the main results of wastewater treatment tank simulations and experiments performed where simulation and experimental results have been close (Weiss, Plósz, Essemiani, & Meinhold, 2007; Hao & Shen, 2020). The decrease of blockages and the larger efficiency of sludge transport evidenced experimentally also confirm the simulation's predictions, showing the reliability of CFD to guide practical improvement design of sludge levels in management systems (Weiss, Plósz, Essemiani, & Meinhold, 2007; Hao & Shen, 2020). This close agreement between CFD-

based simulation outcome and prototype measurement also highlights the benefit of including CFD simulation with physical prototyping to meet specific performance objectives.

Figure 19: Physical prototype

Figure 19 shows the physical prototype of the selected design, the Center Channel Guide, installed in the actual sludge pit. The prototype was fabricated from stainless steel to ensure durability and resistance to corrosion in a wet and chemically active environment. The guiding panel is positioned centrally within the pit to redirect water flow and promote continuous sludge movement toward the desludger. The structure was dimensioned based on CAD modeling to fit precisely within the existing pit layout without requiring structural modifications. Key features such as the angled guiding surface and top-mounted support frame can be seen in the image, demonstrating how the prototype facilitates better water distribution while minimizing dead zones and sludge buildup. This real-world installation served to validate the simulation results and assess the practical effectiveness of the proposed design under operating conditions.

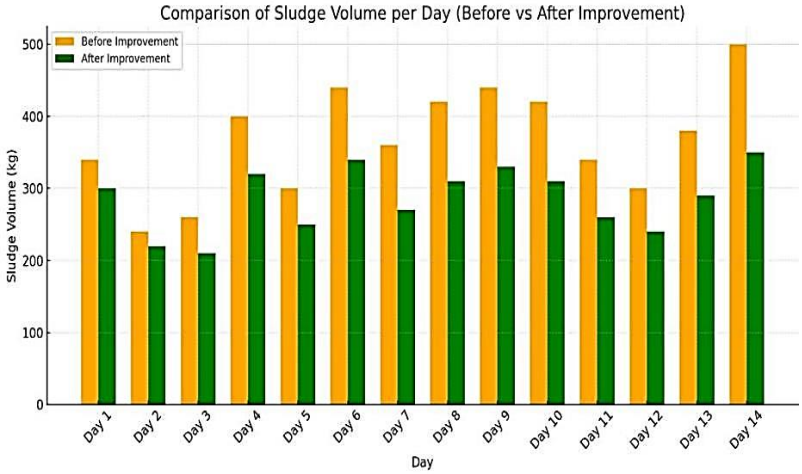


Figure 20: Comparison of sludge volume per day before and after implementing

This graph illustrates a comparison of sludge volume per day before and after implementing the improved design over a 14-day period (Salihoglu & Salihoglu, 2016; Ruffino et al., 2023). The orange bars represent sludge volumes before improvement, while the green bars represent sludge volumes after improvement.

From the visual data, it is clear that sludge volume decreased consistently after the improvement was applied. This indicates that the redesigned pit features (such as flow guides or optimized geometry) significantly helped in reducing sludge buildup, which leads to better flow, reduced maintenance needs, and improved pit system efficiency.

The chart supports the success of the design intervention by showing a visible reduction in sludge volume on all days, demonstrating the improvement's effectiveness in managing sludge flow.

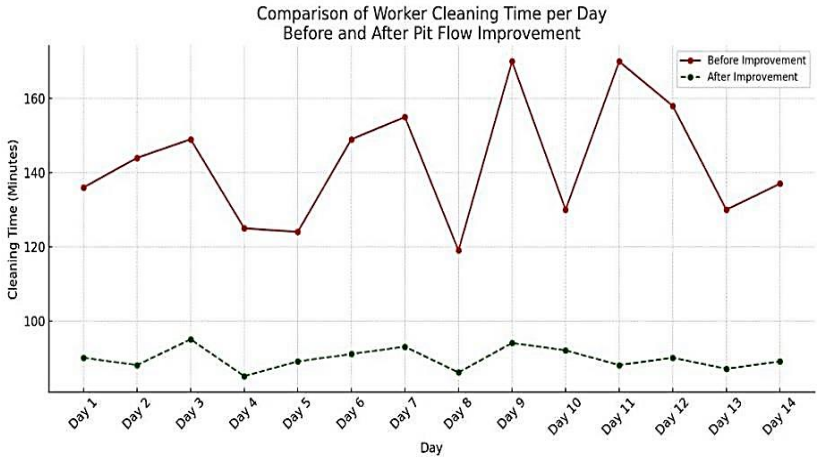


Figure 21: Comparison of worker cleaning time per day before and after the pit flow improvement

This graph shows a comparison of worker cleaning time per day before and after the pit flow improvement across a 14-day period. The red line represents the cleaning time before improvement, and the green dashed line shows the time taken after improvement.

From the graph, it is clear that after the improvement, the cleaning time reduced significantly, indicating better sludge flow and less accumulation in the pit area. This also implies that the new design helped in reducing worker strain, minimizing downtime, and improving overall efficiency.

The consistent drop in cleaning time across all days demonstrates that the optimized pit layout and flow path contributed to smoother sludge movement, making the system easier to maintain.

4.4 Discussion and Implications

The findings of this study indicate that optimizing flow behavior within a sludge pit system can significantly improve maintenance efficiency, reduce downtime, and enhance sludge removal. The combination of CFD analysis, practical field validation, and design innovation ensures that the solution is both technically sound and industrially viable.

Furthermore, the use of engineering software tools such as ANSYS Fluent allowed to visualize and quantify the effects of design changes before physical implementation. This approach reduces trial-and-error and supports data-driven decision-making in production environments.

The improvement in cleaning time also suggests potential labor cost savings and better utilization of manpower. These operational benefits contribute to the broader goals of lean manufacturing and process optimization within the painting line.

This table shows the differences in turbulence behavior between the current and improved sludge pit designs using data from CFD simulations. In the current design, the turbulence peak is higher, and strong turbulence is seen at the inlet and mid-channel, which causes unstable flow and more disturbance throughout the system. The improved design has a slightly lower TKE peak, with turbulence more evenly spread and mainly limited to the inlet and outlet areas. The middle zone is calmer, and the flow is more stable, helping sludge move smoothly and reducing the chances of clogging.

Table 5: Contour Color Interpretation for Velocity and TKE

Color	Velocity Range (m/s)	Flow Behavior Description	TKE Range (m^2/s^2)	Turbulence Level Description
Dark Blue	0.0 – 0.5	Very low flow; potential sludge accumulation	0.000 – 0.100	Very low turbulence; stable region
Green	0.8 – 1.4	Moderate flow; transitional zone	0.101 – 0.250	Moderate turbulence; transitional flow
Yellow	1.5 – 2.0	High flow; effective water transport	0.251 – 0.350	High turbulence; swirling/recirculation zone
Red	2.1 – 2.3	Peak flow; strong directional water movement	0.351 – 0.401	Peak turbulence; unstable, energy- intensive zone

Table 5 provides a combined interpretation of the contour color ranges from the CFD simulation, linking both velocity magnitude and Turbulence Kinetic Energy (TKE) to specific flow behaviors within the sludge pit. Each color in the contour plots corresponds to a defined range of values: dark blue represents very low velocity (0.0–0.5 m/s) and low TKE (0.000–0.100 m^2/s^2), typically indicating stagnant zones where sludge accumulation is likely. Green indicates moderate velocity (0.8–1.4 m/s) and transitional turbulence levels (0.101–0.250 m^2/s^2), suggesting partially stable flow with minor recirculation. Yellow reflects high flow velocity (1.5–2.0 m/s) and elevated TKE (0.251–0.350 m^2/s^2), where water moves more effectively but turbulence may still be present. Red highlights regions of peak velocity (2.1–2.3 m/s) and the highest turbulence levels (0.351–0.401 m^2/s^2), which represent unstable flow and high energy mixing zones. By quantifying these color bands, the table helps interpret simulation results more accurately, allowing critical zones such as dead zones or high-turbulence areas to be identified and addressed in the design.

Table 6: Comparison of Turbulence Kinetic Energy (TKE) Behavior Between Current and Improved Design

Criteria	Current Design	Improved Design
TKE Peak	~0.4017 m^2/s^2 (more red & yellow near inlet)	~0.3519 m^2/s^2 (slightly lower peak)
Distribution	Strong turbulence localized at the inlet bend and some disturbance mid-channel	More even spread, turbulence contained near inlet & outlet
Midstream Area	Higher turbulence in middle zone with some green/yellow spread	Reduced turbulence, mid- pit area shows more blue tones
Flow Stability	Disturbance continues downstream	More stable, better flow profile control

Table 6 shows the key flow differences between the current and improved pit designs. In the current setup, high velocity is mainly seen at the inlet, with stagnation in the middle, leading to dead zones and poor sludge movement. Turbulence is strong and inconsistent, causing areas where sludge tends to build up. In contrast, the improved design has smoother velocity throughout the pit, fewer stagnant zones, better streamline flow, and improved sludge transport due to the bottom channel enhancements.

Table 7: Comparison of Flow Characteristics Current vs Improved Design

Aspect	Current Design	Improved Design
Velocity Uniformity	High velocity only at inlet; midsection shows stagnation	Smoother velocity transition across entire flow path
Dead Zones	More blue regions (0 m/s) especially around corners	Fewer dead zones; better coverage in the bottom area
Turbulence Pattern	Strong swirling near inlet with abrupt slowing	Streamlines more continuous and laminar overall
Sludge Movement	Possible accumulation in slow flow areas	Improved bottom channel flow supports sludge transport

Table 7 summarizes the performance differences between the current and improved sludge pit designs. The improved design provides smoother velocity distribution, reduces dead zones, and creates a more continuous, laminar flow compared to the current design, which suffers from stagnation and turbulence near the inlet. Additionally, the new bottom channel structure supports better sludge movement, minimizing buildup in low-flow areas.

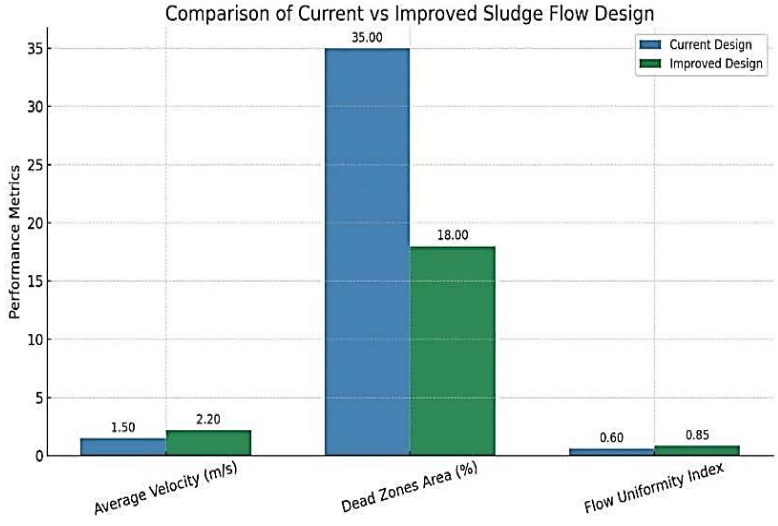


Figure 22: Compares key performance metrics between the current and improved sludge flow designs

Figure 22 shows a clear improvement in sludge flow performance after implementing the new design. The average velocity increased, which means water flows more steadily and helps push sludge more effectively through the system. At the same time, the percentage of dead zones areas where water movement is too slow was greatly reduced, making it less likely for sludge to settle and cause blockages. The flow uniformity index also improved, showing that the flow

became smoother and more consistent across the pit. Overall, the improved design leads to more efficient sludge transport and better system performance.

5.0 CONCLUSION

The proposed flow-improvement design for the painting line sludge pit reduced sludge clogging and enhanced maintenance efficiency. A structured design methodology (including concept generation, CFD simulation, and prototype testing) identified the Center Channel Guide as the design with highest effectiveness. Statistical analysis revealed that sludge volume (417 ± 46.2-260 ± 29.8 kg/shift) and cleaning time (150 ± 13.6-87 ± 6.5 min/shift) were significantly decreased, with enhanced flow velocity and turbulence zones mitigation in CFD studies.

In addition to the quantitative enhancement, the new structure demonstrated to be practicable and simple to include in the old system without major structural changes. The close relationship between the simulation results and the practical performance indicates that the design can be potentially practical for industrial applications.

Nevertheless, there are a few limitations that need to be noted. The CFD studies were conducted in single-phase flow for only water without considering the complex nature of the sludge, which was treated as a non-Newtonian fluid. Furthermore, a smaller prototype was investigated for the experiments, the dynamic similarity and the long-term operation effects were not fully studied. No live physiological signal monitoring was carried out to track trends in performance over the break, which is potentially interesting for future optimization.

A multi-phase CFD model, long-term monitoring with flow meters and turbidimeters and taking sludge rheology into account should be considered in future work to approach the real situation more closely. A comparison between long-term maintenance savings and fabrication cost would also increase the industrial relevance of this approach.

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Optimizing Numerical Control (NC) Sewing Jig Design to Reduce Downtime in The Production Line

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ABSTRACT

In the automotive industry, efficient and accurate sewing processes are essential to ensure high- quality interior components. One such part, the carpet toe kick is assembled using a Numerical Control (NC) sewing jig. However, the current jig design often causes frequent downtime. These problems are mainly due to weak binding tape joints. This study focuses on optimizing the NC sewing jig design to minimize downtime and improve the production process. Root cause analysis was conducted using the Ishikawa Diagram to identify the key issues contributing to performance delays. A new jig design was developed using CATIA V5 software, aiming to improve strength, alignment accuracy and usability. To determine the most effective design, the Pugh method was applied to compare and select the best concept. The new jig design helped cycle time decreased from 191.3 seconds to 168.4 seconds per unit, compared to the existing jig. This study shows that a well-designed NC jig can significantly improve sewing efficiency and provide long-term benefits to the production line.

Keywords: NC sewing jig, cycle time, pugh method

1.0 INTRODUCTION

According to manufacturing guidelines, a jig is a tool that helps guide other tools or parts during production to make sure the work is done accurately and consistently [1]. In car seat sewing, especially for parts like the carpet toe kick, Numerical Control (NC) sewing jigs are very important. They help create clean and repeatable stitching lines [2]. Compared to manual sewing, NC jigs improve stitch quality and reduce mistakes by keeping the fabric on the right path [3]. However, how well a jig works depends on its design things like the strength of its materials, how stable it is and how easy it is to see the stitch lines. Each part may have a different shape, so operators need to set up the jig carefully. If the jig is not set up properly or has a poor design, it can cause stitching errors, slow down production and lead to downtime.

The NC sewing jig must be used according to the work instructions to ensure precise alignment and consistent stitching quality. The jig is a sensitive tool designed to hold fabric securely and accurately during sewing, so operators must handle it carefully to avoid damage or misalignment. Proper setup requires gently securing the fabric and positioning the jig at the correct position to prevent defects such as inconsistent stitching. Accurate use of the NC sewing jig is essential to meet quality standards and maintain the performance and durability of sewn components in the production line. The purpose of the current jig is to maintain consistent and precise fabric positioning during sewing. This paper focuses on designing a new NC sewing jig using CATIA V5 software to improve alignment accuracy and reduce cycle time. Figure 1 below shows the carpet toe kick sewn using NC sewing machine.

Figure 1.1: Finished Goods of Carpet Toe Kick Sewn using NC Sewing Machine

1.1 Problem Statement

The production line is experiencing significant inefficiencies due to recurring issues with the Numerical Control (NC) sewing jigs used for the Carpet Toe Kick part. Frequent downtime is caused by stitching misalignment, which occurs regularly because of poor connection quality between jig components that are currently held together with binding tape prone to shifting during operation. This misalignment leads to inconsistent stitching and results in a high standard deviation in the sewing process. To achieve more consistent stitching, three new designs of NC sewing jigs have been proposed. These improved jigs will better manage fabric alignment and stitching accuracy to meet standard specifications, thereby reducing the standard deviation. An example of inconsistent stitching is shown in Figure 2.

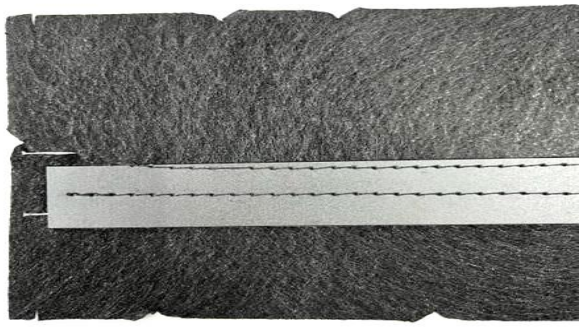

Figure 1.2: Inconsistent Stitching on Part

2.0 METHODOLOGY

The objective of this research is to develop a new NC sewing jig to assist operators in achieving more accurate and consistent stitching while reducing production downtime. Currently, the sewing process for the Carpet Toe Kick 60% PWR/MAN component relies heavily on manual adjustments, with the existing jigs joined using binding tape, which often leads to misalignment. This indicates the need for a redesigned jig to ensure precise fabric alignment and minimize errors during operation. To identify the root causes of these issues, a Fishbone Diagram also referred to as an Ishikawa or cause-and-effect diagram was employed as part of the technical analysis. This tool helps visualize the potential factors contributing to frequent jig failure and stitching defects [4]. A key factor identified was poor structural stability, which

directly affects stitching accuracy and product quality. To address this, three concept designs of the new NC sewing jig were proposed and presented to the development team. The designs were evaluated based on performance, usability and durability criteria using the Pugh method, a structured decision-making tool often used in design and material selection processes [5]. Each design was developed with specific objectives to enhance jig to reduce downtime and improve stitching precision. Performance data were collected from cycle time before and after implementing the new jig, enabling a comparative analysis of stitching quality and production efficiency. Figure 3 illustrates the research methodology followed in this study.

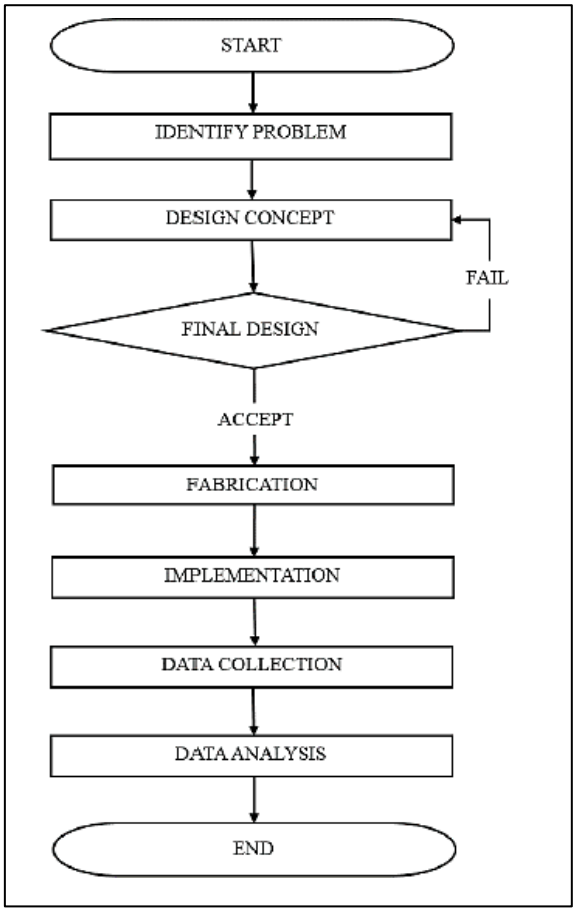

Figure 2.1: Flow Chart of Methodology

2.1 Ishikawa Diagram

In order to methodically determine the underlying reasons for the problem, a fishbone diagram (also known as an Ishikawa or cause-and-effect diagram) was employed, as depicted in Figure 2. The reasons were classified into four primary categories: Method, Man, Machine, and Material.

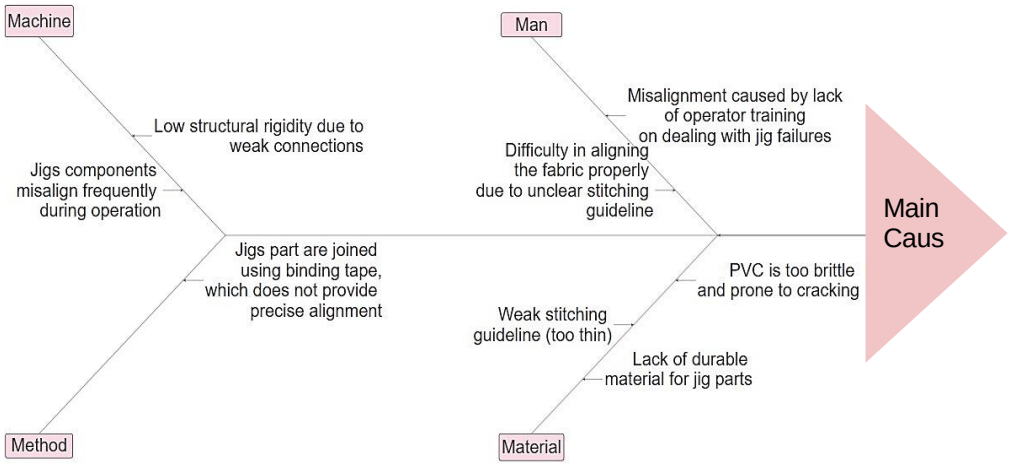

Figure 2.2: Fishbone Diagram

Man - Insufficient operator training and difficulty in aligning fabric due to unclear stitching guides.

Material - The brittle PVC construction results in frequent breakage and poor durability.

Machine - Low structural rigidity of the jig causing misalignment during high-speed operations.

Method - The use of binding tape for assembly leads to unstable and inconsistent jig positioning.

2.2 Data collection

To evaluate how long it takes to sew one unit using the old NC Sewing jig, data was collected from 10 production cycles. Each cycle represents the time required to complete sewing for one Carpet Toe Kick part as shown in Table 2.1.

Table 2.1: Data Cycle Time (before improvement)

Sample No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cycle Time	190	195	185	200	188	192	190	193	189	191
Mean	191.3									
Standard deviation	4.11									

2.3 Concept Design

The proposed design of the new NC sewing jig is based on an analysis of the joining method used to assemble parts in the existing jig. The current design uses binding tape to connect jig components, which has proven to be unstable and often results in component shifting during operation, leading to inconsistent stitching. Therefore, the new design focuses on implementing a more secure and stable joining method, such as the use of hinges and permanent screws, to ensure each part of the jig remains firmly in place throughout the sewing process. This approach

is expected to reduce defects, improve stitching accuracy, and enhance the long-term usability of the jig.

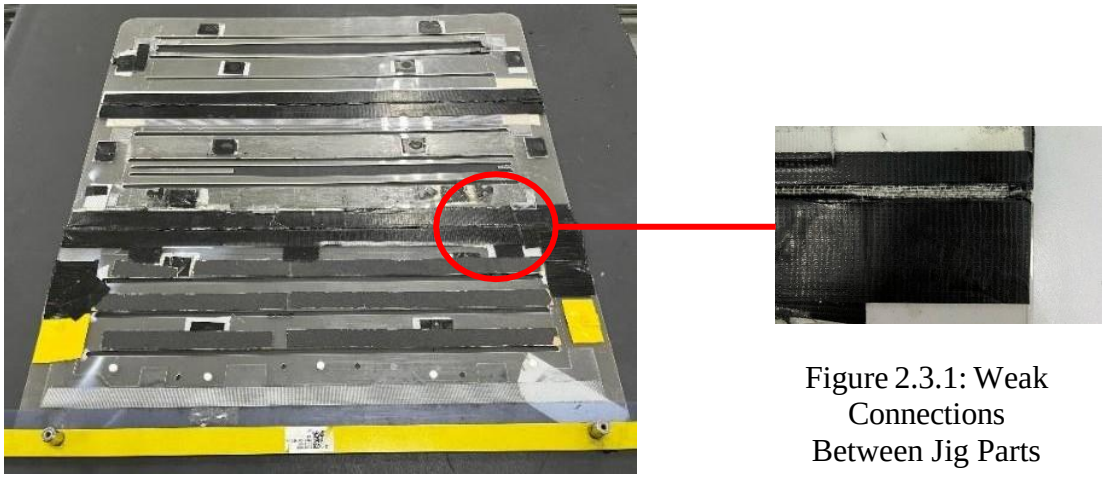

Figure 2.3.1: Weak Connections Between Jig Parts

Figure 2.3: Overview of Problem with The Current NC Sewing Jig

2.4 Pugh Method

The Pugh method is used to evaluate and compare the proposed jig design options based on specific performance criteria. The Pugh method criteria are shown in Table 2.2.

Table 2.2: Criteria of Design

Criteria	Design 1	Design 2	Design 3
Flexibility			
Shape			
Durability			
Total			

3.0 RESULTS AND DISCUSSIONS

The study's Results and Data Analysis part looks at the outcomes of various methods and analyses used to problems with Company X's old NC Sewing Jig. This section aims to give a comprehensive understanding of the project's findings through in-depth analyses, including reading from the Pugh technique. Important details on the effectiveness of solutions put into practice and their implications for manufacturing process optimization will be covered in this section. The table 3 show the result of reading after using the jig. Based on the result, the data has a good result for the cycle time after improvement of NC Sewing Jig. For the discussion, the cycle time after using the new NC sewing jig. This has been proved in comparison of cycle time before and after improvement of NC sewing jig at the company X.

Design 1 which is Figure 3.1 was evaluated during the comparative analysis for optimizing the NC sewing jig. This design provides some flexibility in holding fabric, however it lacks the necessary rigidity and structural stability required for precise and repeatable stitching. The binding ring tends to shift under operational stresses, causing misalignment and inconsistent stitching quality.

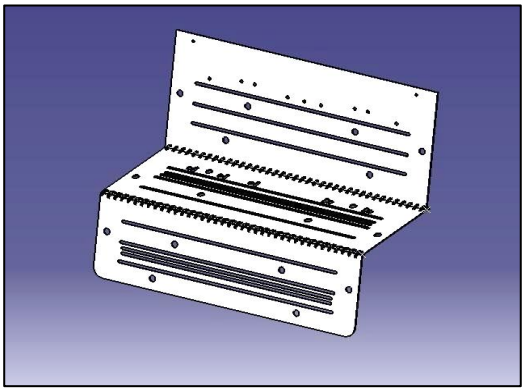

Figure 3.1: Design 1

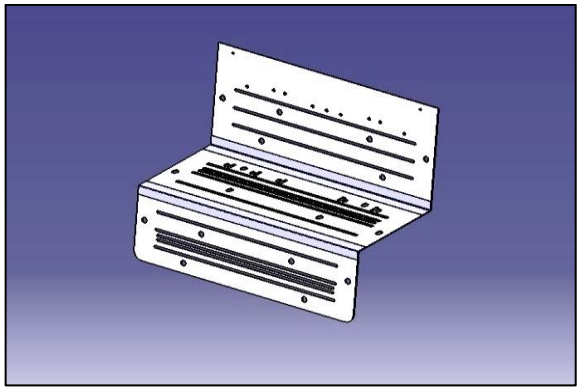

Figure 3.2: Design 2

Design 2 which is Figure 3.2 was assessed for its potential as an alternative jig solution in the NC sewing process. This design demonstrated excellent flexibility, allowing for quick adjustments and temporary fixes during operation. However, it falls short in terms of shape consistency and long-term durability. The foil tape tends to deform easily and lacks the rigidity needed to maintain proper jig alignment during continuous use, which may lead to inconsistencies in stitching accuracy.

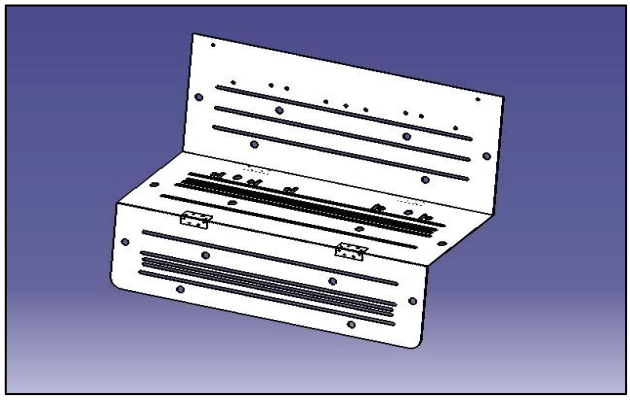

Figure 3.3: Design 3

Design 3 which is Figure 3.3 emerged as the most effective and reliable solution among the evaluated alternatives for the NC sewing process. This design offers a strong balance between flexibility, structural integrity, and long-term durability. The hinged mechanism enables easier setup and alignment while maintaining consistent shape during the sewing operation, which significantly improves stitching accuracy and reduces the risk of defects. Its robust construction allows it to withstand repeated industrial use without deformation or performance degradation. Compared to other options, the hinged jig provides superior alignment control and operational stability, making it highly suitable for enhancing productivity and quality in a high-volume manufacturing environment.

Table 3.1: Pugh Method Data

Criteria	Design 1	Design 2	Design 3
Flexibility	4	5	4
Shape	5	4	6
Durability	5	3	10
Total	14	12	20

Based on the comparative evaluation using the Pugh method in Table 3.1, three jig design options were analyzed according to selected criteria flexibility, shape and durability. The purpose of this method is not to score performance directly, but to compare each design relative to one another using a reference standard. The results show that Design 3 is the most favorable option, receiving the highest total comparative score of 20. Design 1 and Design 2 received scores of 14 and 12, respectively. While Design 2 showed better flexibility, Design 3 stood out in terms of shape and durability. Its ergonomic form and high durability make it more suitable for operator handling and long-term use. Despite having equal flexibility to Design 1, Design 3's overall balance across the evaluation criteria indicates that it is the most suitable design to proceed with for actual production use.

Table 3.2: Data Cycle Time (before improvement)

Sample No.	1	2	3	4	5	6	7	8	9	10
Cycle Time	190	195	185	200	188	192	190	193	189	191
Mean	191.3									
Standard deviation	4.11									

Table 3.3: Data Cycle Time (after improvement)

Sample No.	1	2	3	4	5	6	7	8	9	10
Cycle Time	168	172	169	170	165	167	166	168	169	170
Mean	168.4									
Standard deviation	2.07									

Based on Table 3.2 and Table 3.3, the cycle time per unit was reduced, indicating an improvement in process efficiency following the implementation of the new NC sewing jig design. The decrease in the mean value signifies an improvement in performance when the new NC sewing jig is utilized, potentially reflecting better stitching accuracy and more efficient operation. Additionally, the lower standard deviation indicates that performance has become more consistent and reliable, supporting the conclusion that the NC sewing jig enhances overall process stability and quality.

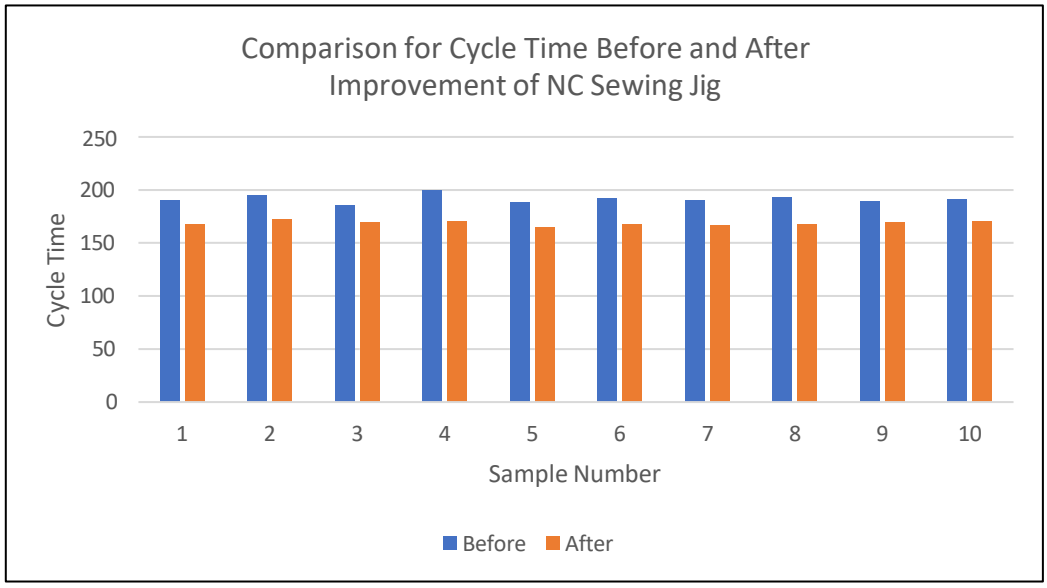

Figure 3.1: Bar Graph of Comparison for Cycle Time Data Before and After Improvement

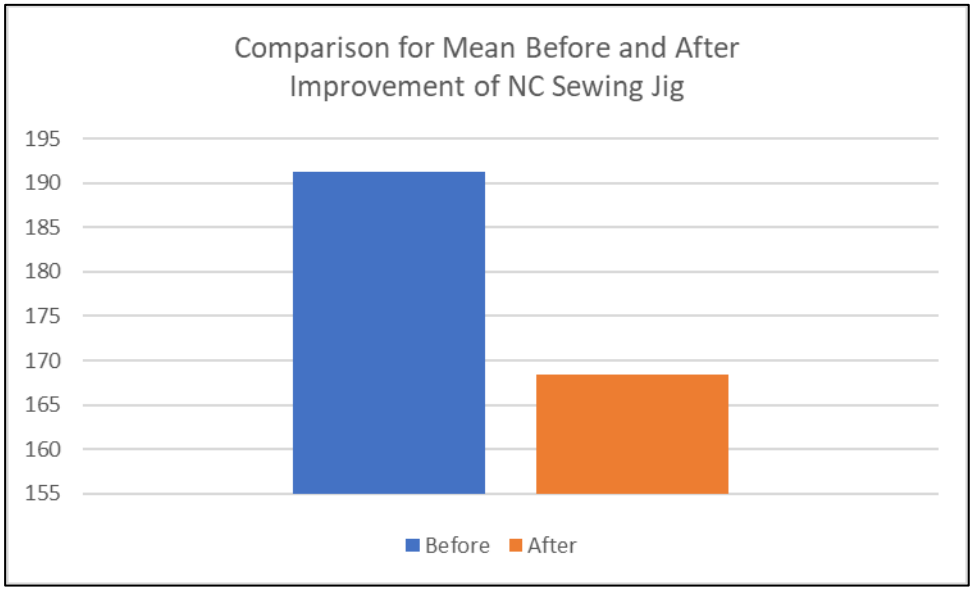

Figure 3.2: Bar Graph for Mean Before and After Improvement

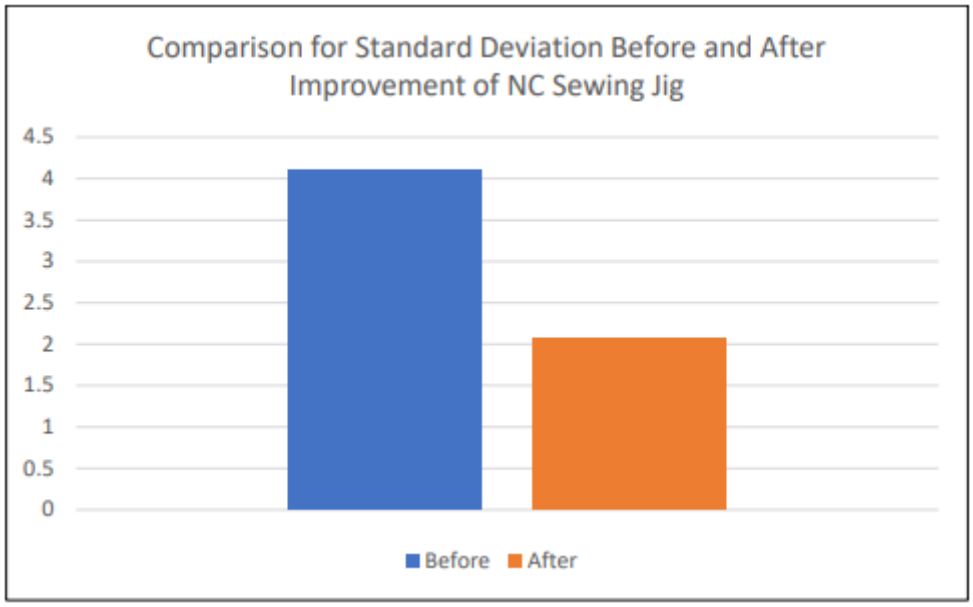

Figure 3.3: Bar Graph for Standard Deviation Before and After Improvement

4.0 CONCLUSION

This study successfully met its primary objectives by designing a new NC sewing jig for the Carpet Toe Kick 60% PWR/MAN component using CATIA V5 software. The redesigned jig resulted in a notable reduction in cycle time, decreasing from 191.3 seconds to 168.4 seconds per unit, which demonstrates improved process efficiency and a smoother production workflow. Overall, the findings validated that the new jig design effectively enhances production performance by minimizing downtime, improving stitching quality and increasing overall operational efficiency.

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Reducing Operator Strain in Armrest Manufacturing by Designing an Ergonomic Trolley for the GP-12 Workstation

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ABSTRACT

The GP-12 workstation in Company W's Model J Armrest production line faces ergonomic and operational challenges that affect worker safety and productivity. This study aims to design an ergonomic trolley to improve handling efficiency, reduce physical strain, and enhance workflow. The methodology involved problem identification, data collection, development of conceptual designs, evaluation using the Pugh Matrix, 3D modeling using CATIA V5, ergonomic simulation using CATIA V5 Manikin, and assessment using the REBA sheet. Design constraints were identified through Gemba walks, site observations, and discussions with operators and maintenance staff. The selected design outperformed alternatives in ergonomics, functionality, and manufacturability. REBA assessment showed a risk reduction from high (scores 8–9) to low (scores 2–3), confirming reduced physical strain. In conclusion, the ergonomic trolley design successfully addressed the issues at the GP-12 workstation, with REBA results demonstrating clear ergonomic improvement.

Keywords: design, ergonomics, trolley, pugh matrix, design area constraint

1.0 INTRODUCTION

Company W is a renowned manufacturer of vehicle interior components, recognized for its commitment to quality and operational excellence. The Quality Assurance Department has been assigned to address the ongoing issue of worker absenteeism at the GP-12 workstation, where frequent medical leaves have become a significant concern. Workers have also raised complaints about fatigue caused by the current work sequence, particularly due to the use of ordinary trolleys that are unsuitable for their tasks. The existing trolleys require additional lifting and forceful efforts when handling each box for inspection, contributing to physical strain and further absenteeism. This research aims to design an ergonomic trolley that addresses these challenges by improving the workstation's work sequence, reducing the physical effort required, and ultimately enhancing worker comfort and efficiency. The goal is to ensure a smoother, safer, and more sustainable work process that maintains the high-quality standards expected for the armrest products for model J.

1.1 Problem Statement

Company W, a manufacturer of interior vehicle parts, has identified an operational issue in the armrest production line, specifically at the GP-12 workstation. Figure 1 shows this workstation involves lifting boxes containing armrests of model J shows at Figure 2. Workers assigned to GP-12 frequently take medical leave, which upon investigation, is primarily caused by fatigue due to the high work frequency and physical strain of lifting heavy boxes. Furthermore, the use of ordinary trolleys at this workstation contributes to worker fatigue, as it forces workers into awkward body positions and still requires them to lift heavy boxes manually. This fatigue

negatively impacts workers' ability to perform thorough final inspections, resulting in decreased attention and missed quality defects. Consequently, defective products are occasionally delivered to customers, leading to quality issues and potential dissatisfaction. This situation affects both worker health and product quality, thereby hindering production efficiency and customer satisfaction.

Figure 1: Standard trolley not suitable

Figure 2: Rear Armrest of Model J

1.2 Objective

The objective of this research is to design an ergonomic trolley for the GP-12 workstation in the Model J Armrest production line, aiming to enhance the efficiency and ease of handling and transportation of armrest products by reducing physical strain, improving work sequence, and increasing overall productivity while ensuring the safety and comfort of the workers involved in the production process.

2.0 METHODOLOGY

This study adopts a systematic engineering design approach for developing the trolley as shown

at Figure 3, which involves identifying design limitations, creating conceptual options, and assessing them using the Pugh Matrix (Okuyucu & Tanık, 2023). The Pugh Matrix, a decision-matrix technique, provides a structured method to compare multiple design alternatives against a baseline by applying specific criteria. It facilitates complex decision-making by scoring each option relative to the baseline, helping engineers select the most balanced and effective solution based on weighted performance factors (Guler & Petrisor, 2021). This method ensures an impartial evaluation and selection of the optimal trolley design for the GP-12 workstation. Following the Pugh Matrix evaluation, the chosen trolley design was modeled using CATIA software in accordance with the defined design constraints.

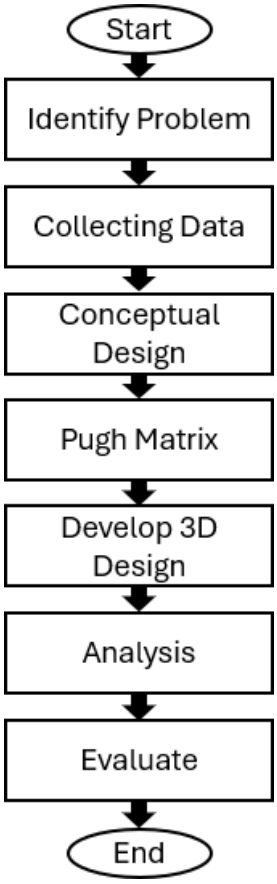


Figure 3: Method for Design the Trolley

2.1 Problem Identification and Data Collection

The initial phase involved identifying ergonomic and operational issues at the GP-12 workstation through Gemba walks, site observations, and interviews with operators and maintenance staff. These activities helped capture current handling issues, poor posture risks, and workflow inefficiencies. Gemba Walks, as noted by Mičieta et al. (2021), are effective in observing real-time workplace activities and uncovering root causes of inefficiencies.

2.2 Conceptual Design Development

Based on the findings, several conceptual trolley designs were generated to address identified ergonomic issues. Conceptual design plays a crucial role in the early stage of engineering development, allowing iteration based on function and user needs (Yang et al., 2023).

2.3 Design Selection Using the Pugh Matrix

The Pugh Matrix was employed to evaluate and compare the conceptual designs against a baseline (Dantum) design. Criteria included ergonomics, functionality, manufacturability, and cost. This method allows systematic selection and refinement of design alternatives (Okuyucu & Tanık, 2023; Guler & Petrisor, 2021). The Pugh method was chosen for its suitability in small design team environments and decision loops that support elimination and updating of weak design elements (Li & Shi, 2024).

2.4 3D Modeling Using CATIA V5

The selected trolley design was modeled in detail using CATIA V5, incorporating ergonomic elements such as handle position, load height, and wheel placement. The 3D modeling phase served as the foundation for ergonomic simulation and technical refinement.

2.5 Ergonomic Simulation Using CATIA V5 Manikin

The design was assessed using CATIA V5's Manikin simulation tool, allowing posture evaluation, reach analysis, and usability validation under typical working conditions. This tool enabled a more accurate prediction of physical strain during operation.

2.6 Ergonomic Assessment Using REBA

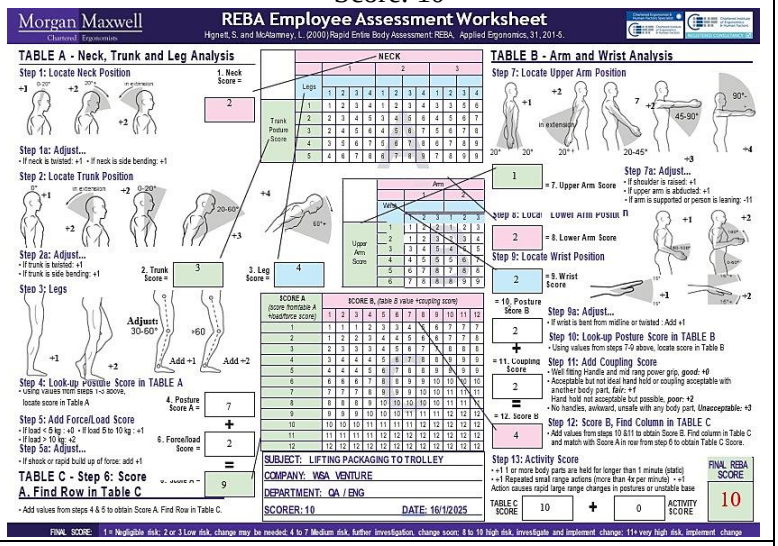
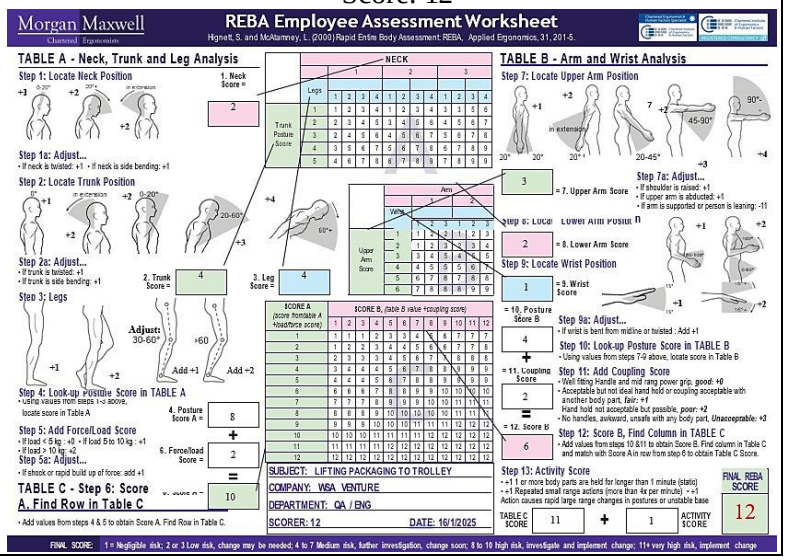
To quantitatively assess ergonomic performance, the Rapid Entire Body Assessment (REBA) method was applied to postures simulated using CATIA V5. REBA scoring helped determine risk levels and justified design improvements. Similar ergonomic approaches have been applied effectively in trolley design by Siska and Syahbana (2020).

3.0 RESULTS AND DISCUSSION

3.1 REBA Assessment Worksheet (Before)

The REBA Assessment Worksheet results shown in Table 1 indicate that the existing working posture at the GP-12 workstation falls within a high risk category, highlighting the urgent need for ergonomic improvements to reduce physical strain and prevent musculoskeletal disorders among workers.

Table 1: Listing REBA Result (Before)

Activity	REBA Score
Lifting packaging to trolley	Score: 10 
Activity	**REBA Score**
Lifting packaging to pallet	Score: 12 

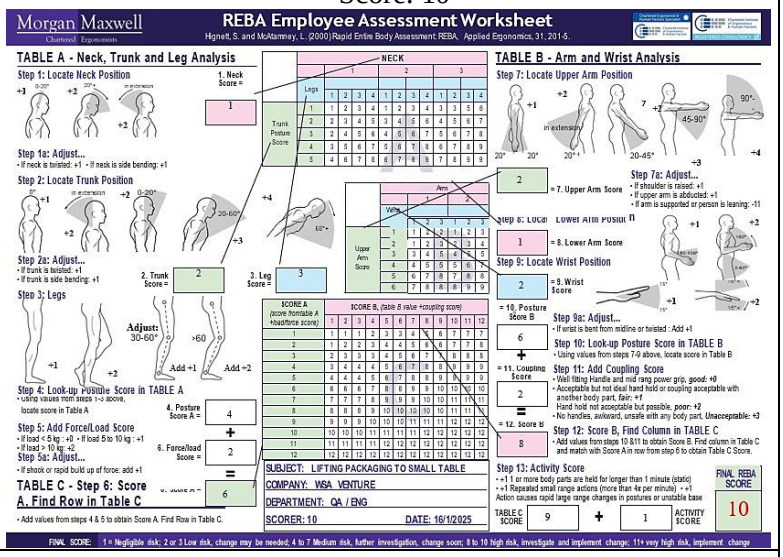
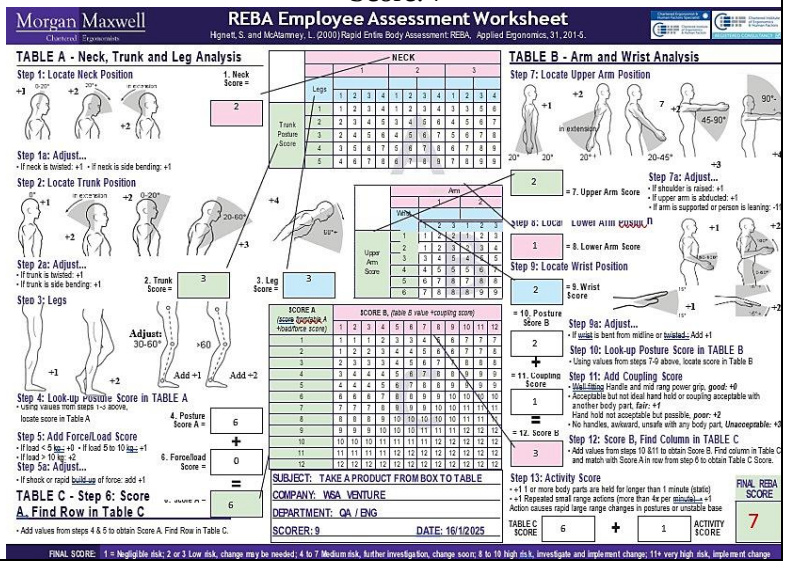
Lifting Packaging to Small Table	Score: 10 
Take out Armrest from Box	Score: 7 

Table 1 presents the REBA assessment results for tasks performed using the standard trolley at the GP-12 workstation. The scores range from 7 to 12, indicating high to very high levels of ergonomic risk according to REBA classification. These values suggest that workers are exposed to significant musculoskeletal strain during manual handling tasks, particularly due to poor posture, repetitive movements, and awkward reach angles. The highest scores were observed during bending, lifting, and loading activities, which require frequent upper body twisting and static holding. Based on these findings, immediate ergonomic intervention is required to reduce the physical burden on operators and minimize the risk of injury. The results served as a baseline reference for evaluating the effectiveness of the proposed ergonomic trolley design.

3.2 3D Design

Based on the selected concept determined using the Pugh Matrix, Figure 3 and Figure 4 illustrate the finalized 3D design of the ergonomic trolley, including detailed views of the structure, a draft of the bill of materials, and key measurements, all of which reflect the design's suitability for the GP-12 workstation requirements.

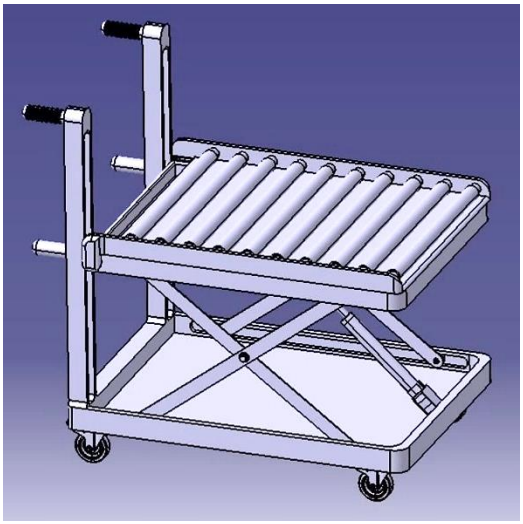


Figure 3: Adjustable Height Trolley Mode

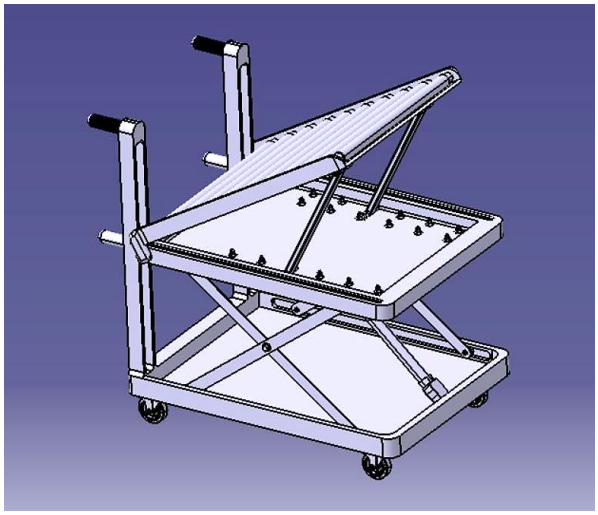


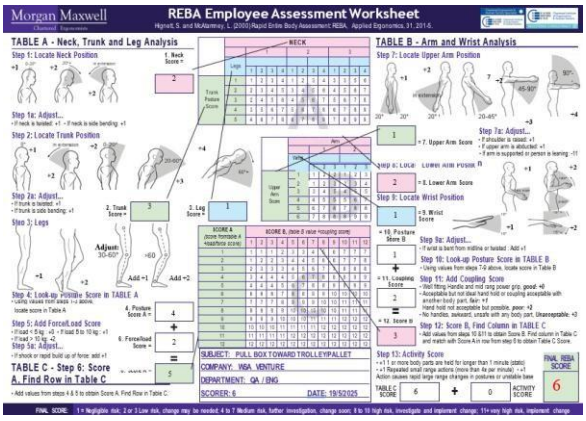
Figure 4: Adjustable Angle of Base Trolley Mode

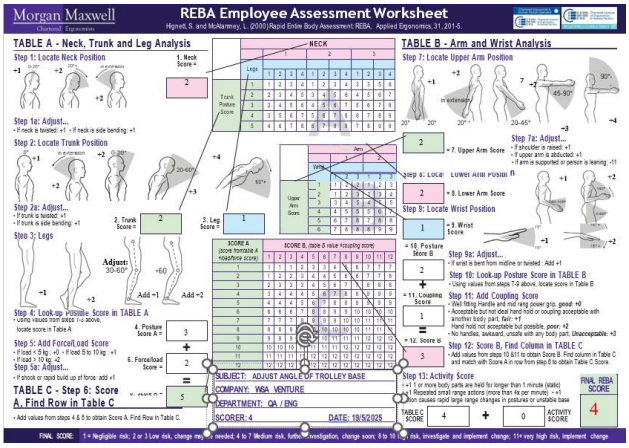
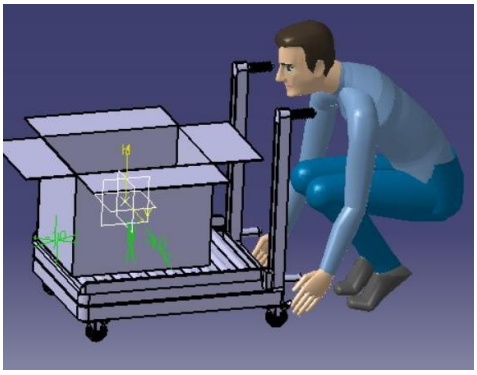
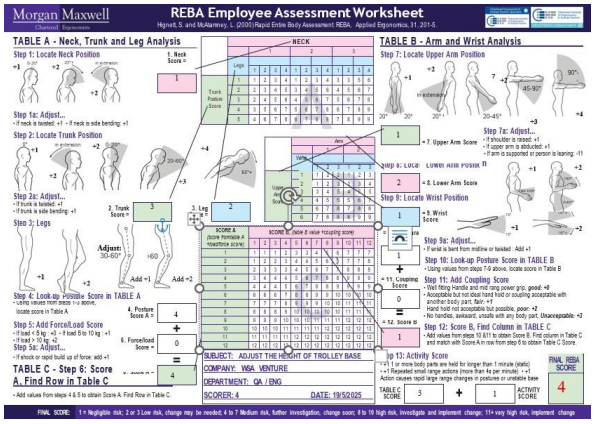
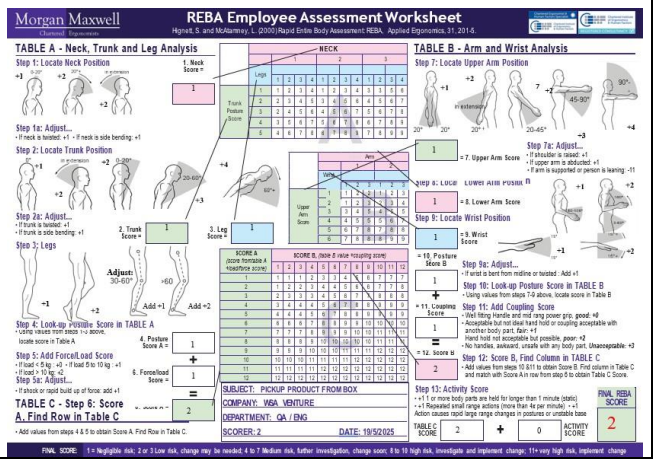
Several conceptual trolley designs were proposed to address the identified ergonomic issues. To facilitate an objective and effective decision-making process, the Pugh Matrix method was applied to evaluate and compare these alternatives against a baseline design. This systematic approach helped narrow down the options by scoring each design based on key criteria such as ergonomics, functionality, and manufacturability. As a result, the design with the highest overall score was selected for further development and refinement which is on Figure 3 and Figure 4.

3.3 REBA Assessment Worksheet (After)

The REBA Assessment results in Table 2 demonstrate a notable improvement in worker posture after the implementation of the new ergonomic trolley through simulation, with REBA scores decreasing from a high-risk level to a lower-risk range, confirming the effectiveness of the design in reducing physical strain at the GP-12 workstation.

Table 2: Listing REBA Result (After)

Activity	REBA Score
Pull the box toward trolley	Score: 6 

Adjust the angle of the trolley base	Score: 4
	
Adjust the height of the trolley	Score: 4
	
Pickup Armrest inside Box	Score: 2
	

The REBA Assessment results in Table 2 demonstrate a significant improvement in worker posture and ergonomic conditions following the implementation of the new ergonomic trolley through simulation, with the REBA score decreasing from a high-risk level to a lower-risk range of 2 to 6, indicating reduced physical strain and a safer working posture at the GP-12 workstation.

3.4 Evaluate Improvement

The comparison of improvements shown in Table 3 highlights the positive impact of the new ergonomic trolley design, including reduced REBA scores, improved posture, lower physical strain, and enhanced compatibility with job requirements at the GP-12 workstation, validating the effectiveness of the proposed solution.

Table 3: Comparison in REBA Score Before and After

	REBA Score	
Work Sequence	**Before**	**After**
Transfer Packaging to Trolley/Pallet	10 and 12	6
Preparation the packaging before take out the armrest to inspection	10	2 and 4
Take out Armrest from the box	7	2

As shown in Table 3, a comparative ergonomic analysis was conducted to evaluate the effectiveness of the proposed trolley design compared to the existing standard trolley. Using the Manikin simulation tool in CATIA V5, typical operator postures were simulated for both designs. These postures were then assessed using the REBA (Rapid Entire Body Assessment) method. The standard trolley recorded REBA scores ranging from 7 to 12, indicating high to very high ergonomic risk levels. In contrast, the proposed ergonomic trolley achieved improved REBA scores between 2 and 6, reflecting low to moderate risk. This significant reduction in ergonomic risk confirms that the new design effectively minimizes physical strain and improves operator safety during material handling tasks.

4.0 CONCLUSION

In conclusion, this research successfully achieved its objective of designing an ergonomic trolley for the GP-12 workstation in the Model J Armrest production line. Through the application of the Pugh method, multiple design concepts were systematically evaluated based on key criteria including ergonomics, functionality, and manufacturability. The selected design, which scored highest in both rank and overall performance, effectively addresses the need to reduce physical strain, improve the work sequence, and enhance the handling and transportation efficiency of armrest products. Following the selection, a detailed 3D model of the chosen design was produced using CATIA software, providing a precise and practical visualization for future implementation. This approach ensures that the new trolley design not only increases overall productivity but also promotes worker safety and comfort within the production process

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Reducing Smoke Opacity in Turbo Diesel Engines via Real-Time Emulsified Systems

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ABSTRACT

Diesel engines, while efficient, emit harmful smoke that impacts health and the environment. This study examines the effect of water content in diesel-water emulsions on smoke opacity using a Nissan Navara turbo diesel engine with a Real-Time Emulsified Fuel Delivery System (RTES). Tests were conducted at 800–2000 RPM with emulsions containing 8%, 10%, 12%, and 15% water. Smoke opacity was measured using a HORIBA MEXA Smoke Analyzer. Results show that the 10% water emulsion (E10) consistently produces the lowest smoke opacity, indicating optimal combustion and reduced emissions. Emulsions with more than 10% water increased smoke due to instability, indicating that a 10% water content optimally reduces smoke emissions without compromising engine performance.

Keywords: diesel emulsion, smoke opacity, turbo diesel engine, emission reduction, RTES

1.0 INTRODUCTION

Diesel engines have long been celebrated for their unparalleled fuel efficiency, durability, and adaptability across various industrial sectors. These consist of power generation, transportation, and agriculture. Diesel engines are essential all over the world because of their capacity to operate dependably under trying circumstances, especially in settings where high power output is essential. Nevertheless, in spite of these important benefits, the extensive use of diesel engines has resulted in significant environmental problems. One of the main issues is smoke emissions, which are a major cause of air pollution. This smoke, which is a result of incomplete combustion, is harmful to human health in addition to having an adverse effect on the environment. It is known to exacerbate cardiovascular and respiratory conditions, which leads to an increase in chronic illnesses. Furthermore, the presence of smoke in the atmosphere exacerbates broader environmental issues, including the formation of smog, which can significantly affect air quality and visibility. Over time, these pollutants also play a role in accelerating climate change, further underscoring the need for cleaner alternatives in diesel engine technology (Akintunde & Owoeye, 2020; Singh & Verma, 2019).

This study's main goal is to use a smoke analyzer to measure smoke opacity through a series of controlled experiments. Both pure diesel fuel and diesel-water emulsions—with water contents varying from 8% to 15% will be the subject of these experiments. The study seeks to measure smoke opacity, a crucial indicator of combustion quality and pollutant emissions, accurately and consistently by carefully regulating the testing conditions. Since adding water to diesel fuel has been proposed as a way to lessen smoke and harmful emissions during combustion, the use of diesel-water emulsions is particularly interesting (Guo, Wang, & Zhang, 2022; Pan, Liu, & Ma, 2021). This experiment will yield important information about the effects of varying water concentrations on diesel engine smoke output.

The investigation will examine the effects of different water contents on smoke opacity in the diesel-water emulsions after the measurement phase. The relationship between the percentage of water and the decrease in visible smoke emissions will be ascertained with the aid of this analysis. Determining the ideal water content that strikes a balance between environmental benefits and performance requires an understanding of this effect. In the end, the results will help evaluate whether diesel-water emulsions can be a cleaner substitute for pure diesel, providing information for creating plans to reduce smoke pollution and enhance air quality (Nguyen, Tran, & Le, 2020; Kumar & Sharma, 2021).

2.0 DETAIL OF THE EXPERIMENT

2.1 Specific Vehicle

In Figure 1, the study utilized a Nissan Navara, with Table 1 representing typical turbo diesel and common rail engine configurations. These vehicles were retrofitted with RTES, with modifications made to optimize compatibility and performance. Detailed documentation of engine specifications, including displacement and fuel system design, ensured the reproducibility of the experiments (Liu, Zhang, & Chen, 2019).

Figure 1: Nissan Navara Vehicle Test

Table 1: Specification Nissan Navara

Parameter	Specification
Model	Nissan Navara
Power	190 Hp @ 4000 rpm.
Torque	450 Nm @ 2000 rpm.
Engine location	Front, Transverse
Engine displacement	2488 cm^3
Number of cylinders	4
Position of cylinders	Inline
Cylinder Bore	89 mm
Piston Stroke	100 mm
Compression ratio	15
Number of valves	16
Fuel System	Diesel Common rail
Engine aspiration	Turbocharger, Intercooler

2.2 Fuel Preparation

Table 2 shows fuel preparation. Petronas Dynamic Diesel B20 was selected as the baseline fuel, and for good reason. Known for its high cetane index, this fuel offers faster ignition and more stable combustion. The research team needed a fuel that could provide consistency throughout every test cycle — something that wouldn't cause variation in the engine's response. B20, which contains 20% biodiesel blended with 80% petroleum diesel, was the perfect candidate. During the preparation phase, the team filled the test rig with Petronas Dynamic Diesel B20. The engine started smoothly, producing a steady idle with minimal vibration (Hsieh & Huang, 2020). The detail is shown in the table below:

Table 2: Fuel Preparation Detail

Properties	Value
Cetane Index	45
Density @ 15°C, kg/m³	815
Kinematic Viscosity @ 40°C, cSt	
Sulphur, % m/m	0.5
Distillation, recovery @ 300°C, % vol	40
Final Boiling Point, °C Nil Pour Point, °C	18
Flash Point, °C	60
Conradson Carbon Residue, % m/m	0.1
Copper Corrosion	1
Ash, % m/m	0.01
Sediment, % m/m	0.01
Total Acid No., mg KOH/g	0.6

2.3 Characteristic Tap Water

Table 3, representing detailed tap water, commonly used in diesel-water emulsions, has several important characteristics that influence the stability of the emulsion and the resulting emissions. It generally contains dissolved minerals and impurities, which can affect the emulsification process. Proper treatment or filtration of tap water is often necessary to ensure a stable emulsion that prevents phase separation during storage and engine operation (Zhang, Wu, & Zhou, 2019).

When combined with diesel fuel, tap water forms a diesel-water emulsion where fine water droplets are dispersed within the diesel. This dispersion improves the combustion process by promoting micro-explosions of water droplets inside the combustion chamber, which enhances fuel atomization and mixing with air. As a result, combustion becomes more complete and efficient (Chen & Liu, 2019). The table below shows the detail of tap water:

Table 3: Detail Tap Water

Specification	Tap Water
Density, g/cm³, 25	1.02412
Specific conductivity, µS/cm, 25ºC	0.0532
Viscosity, millipoise, 25ºC	9.02
Vapour pressure, mm Hg, 20 ºC	17.4
Isothermal compressibility, vol/atm, 0 ºC	46.4 E-6
Surface tension, dyne/cm, 0°C	72.74
Specific heat, J/g ºC, 17.5oc	3.898
The temperature of maximum density, ºC -3.25	-3.25
Freezing point, ºC	-1.91

2.4 Real Time Emulsified Fuel Delivery System (RTES)

The metal mechanical part depicted in the figure 2 may represent an emulsification injector or a specially designed injection valve used in test engine configurations. Before the diesel entering the engine for combustion, it serves the primary purpose of introducing and mixing diesel with water in precise ratios, such as 8%, 10%, 12%, or 15%. This procedure is a component of research on how diesel-water emulsion affects smoke opacity, particularly how well it lowers exhaust's visible smoke. A consistent mixture was produced as the emulsified fuel passed through this injector, entering the engine and burning under real-time conditions. The smoke opacity at each water content level was recorded using RTES. For these tests to be successful, this element is essential. It guarantees the water-diesel emulsion's consistency, enabling the research team to produce accurate and repeatable results. Uneven combustion and inaccurate data could result from any mixture irregularities. As a result, through mechanical accuracy and regulated fuel delivery, this injector helps determine the ideal water content for smoke reduction and advances cleaner combustion methods (Wang & Zhang, 2022; Kumar & Sharma, 2021).

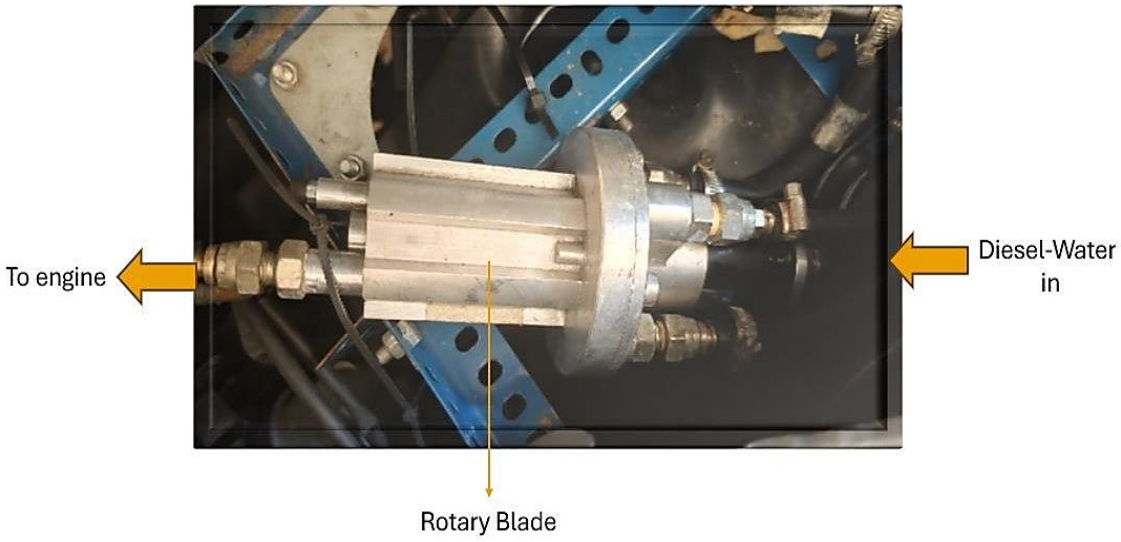

Figure 2: Real Time Emulsified Fuel Delivery System (RTES)

2.5 Test Setup

The figure 3 shown about test setup experiment was conducted in the laboratory at Universiti Teknologi Malaysia (UTM), Kuala Lumpur, using a Nissan Navara mounted on a roller dynamometer to simulate real driving conditions. The vehicle engine was tested at four different speeds 800, 1000, 1200, and 1500 RPM while using diesel fuel emulsified with varying water contents of 8%, 10%, 12%, and 15%. A water tank and pump supplied water through a solenoid valve to ensure precise control of the water percentage in the fuel mixture. The real-time emission system (RTES) installed inside the vehicle continuously monitored exhaust emissions, while a smoke analyzer measured smoke opacity to assess particulate emissions and combustion efficiency. Additional instruments, including a flow rate meter and a control unit, regulated and coordinated the fuel-water mixing and engine parameters. All measurements, including speed, emission levels, and smoke opacity, were logged by a data logger for detailed analysis. This setup allowed for controlled and systematic evaluation of how different water emulsification levels affected the vehicle's emission performance at various engine speeds (Akintunde & Owoeye, 2020; Liu, Zhang, & Chen, 2019).

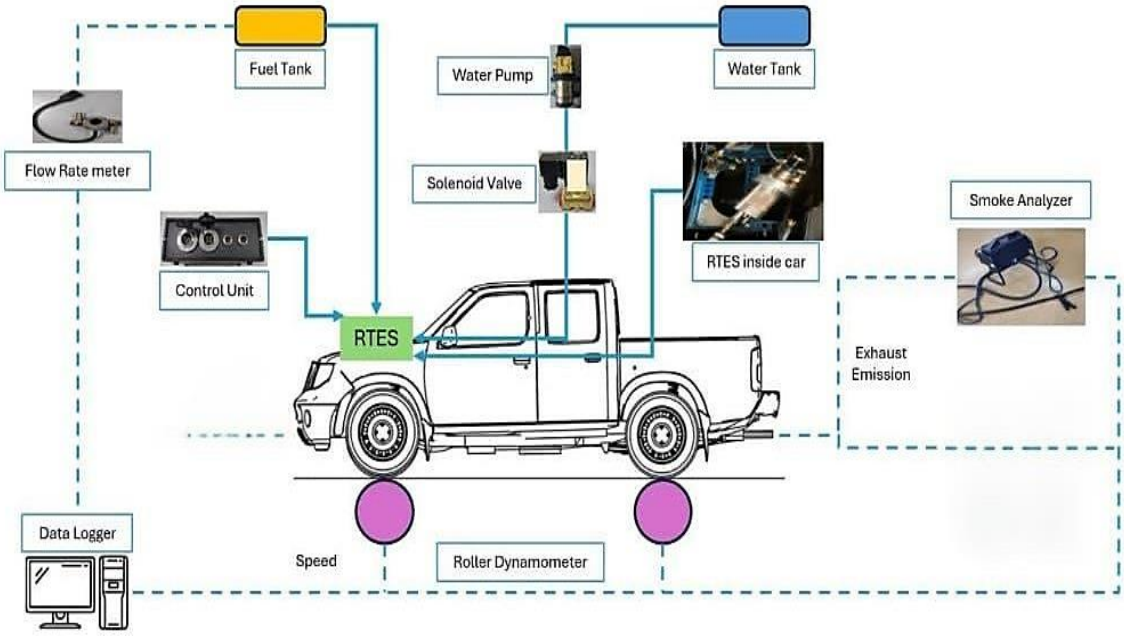

Figure 3: Test on Dynamometer

2.6 Conceptual Diagram of Real-Time Emulsion System for Navara Engine

The conceptual diagram illustrates the real-time emulsion system (RTES) designed for a Navara engine. The system integrates two main fluid sources: a water tank and a diesel tank. Water is pumped from the water tank via a water pump controlled by a solenoid valve, which regulates the flow through a clear tube. Diesel fuel flows from the diesel tank, passing through a flow sensor to measure its rate before being combined with the water flow. Both the water and diesel flows are monitored and controlled by a central controller powered by a car battery. The pressure gauge measures the pressure within the system to ensure proper emulsion conditions. The water and diesel streams converge at a T-joint, entering the RTES unit where the emulsion process occurs.

The processed emulsion then travels through a pressure gauge and a pipe converter, adjusting the pipe size from 8 mm to 10 mm before reaching the engine. Additionally, a fuel return line facilitates the return of unused fuel from the engine back to the system. The diagram 4 clearly

distinguishes electric wire signals, fuel flow lines, and water flow lines, indicating the integration of mechanical and electronic components to maintain precise control and monitoring of the real-time emulsion process, thereby optimizing engine performance.

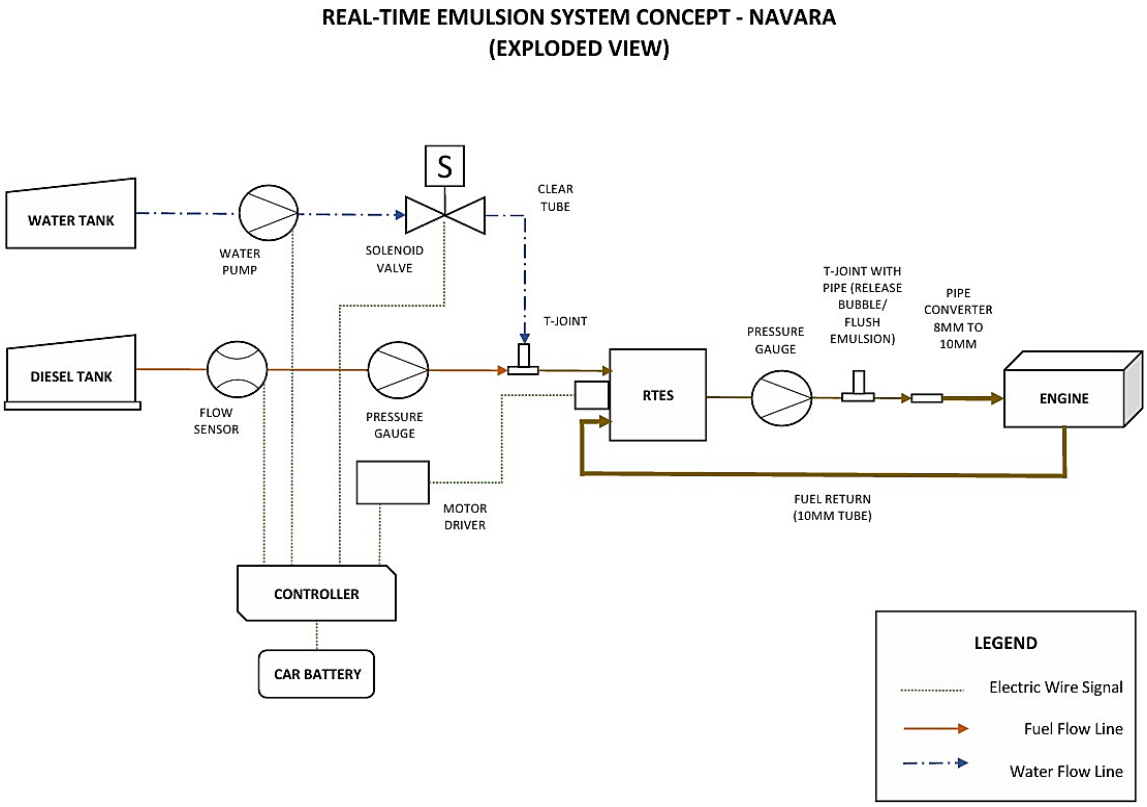

Figure 4: System of RTES

2.7 Matrix Model

The Horiba Mexa in figure 5 is smoke analyzer to measure smoke opacity, expressed as a percentage (%). Smoke opacity is a key indicator of particulate matter emissions, with higher percentages reflecting denser and more visible smoke. Particulate emissions are particularly relevant in diesel engines, which are known to produce more visible exhaust compared to gasoline engines. Similar to the first table, smoke opacity is measured across three trials for each fuel type and RPM level, and averages are calculated to summarize the findings.

Figure 5: Horiba Mexa

2.8 Data Analysis Method

A chart of statistical analysis is a helpful tool for understanding and analyzing data. Mathematical methods are employed to describe and summarize data as well as to test

hypotheses regarding the relationships between variables. Interpreting the information and using it to make decisions.

The goal of statistical analysis is to make one of the most important aspects of statistical analysis is descriptive statistics. This type of analysis results in data descriptions and summaries that are simple to comprehend. These metrics offer a comprehensive grasp of the data distribution and can be used to identify patterns and trends.

3.0 RESULT AND DISCUSSION

3.1 Discussion

The discussion section is derived from the analysis of the data, where the observed trends and patterns are interpreted and explained in the context of the study. It involves connecting the results to the underlying principles of combustion and emission control, assessing how different fuel blends and engine speeds influence smoke opacity. This section also compares the findings with existing literature to validate or challenge previous knowledge. Additionally, the discussion identifies any anomalies or limitations in the data, providing insights into possible causes and suggesting areas for future research. Ultimately, the discussion emphasizes the significance of the results in improving engine performance and reducing environmental impact (Singh & Verma, 2019; Pan, Liu, & Ma, 2021). According to the study by (Ramlan et al., 2020), E10 demonstrates superior emission characteristics, resulting in reduced particulate matter or visible smoke in the exhaust. This reduction in smoke emissions can be attributed to the improved combustion conditions achieved with E10, which promotes more efficient burning of the fuel. Conversely, higher blends like E12 and E15 tend to increase smoke emissions, likely due to less stable combustion and incomplete fuel burning at certain engine speeds, leading to higher particulate output. Diesel fuel, while generally producing lower smoke emissions at higher RPMs, emits more smoke at lower speeds compared to E10. The findings highlight that E10 offers an optimal balance in combustion performance that minimizes smoke emissions without requiring engine modifications, making it a practical choice for reducing environmental pollution from diesel engines. Thus, E10 is recommended as the most effective blend for lowering smoke emissions and improving air quality in diesel-powered vehicles.

3.2 Data Smoke Opacity %

The data in table 4 comparing smoke opacity emissions for diesel and its water emulsions with different water ratios clearly shows that the diesel-water emulsion with 10% water content (E10) exhibits the best performance in terms of reducing smoke emissions across all engine speeds. At 800 rpm, E10 records a smoke opacity of 7%, which is lower than both pure diesel and other emulsions with 8%, 9%, and 11% opacity for E8, E12, and E15, respectively. This trend continues consistently at higher engine speeds, with E10 maintaining the lowest smoke opacity of 8%, 6%, and 5% at 1,000, 1,500, and 2,000 rpm, respectively. The presence of water in the diesel emulsion improves combustion by enhancing fuel atomization and promoting more complete burning, thereby reducing particulate matter emissions. However, increasing the water content beyond 10% (such as in E12 and E15) appears to cause combustion instability, leading to higher smoke opacity. Pure diesel, without water, generally shows higher smoke opacity, indicating that water emulsification helps reduce emissions effectively, with the 10% water ratio striking the best balance between combustion efficiency and emission reduction.

Table 4: Result Data Smoke Opacity

Smoke (%)					
RPM	Diesel	E8	E10	E12	E15
800 rpm	10	9	**7**	8	11
1,000 rpm	11	10	**8**	9	12
1,500 rpm	9	8	**6**	7	10
2,000 rpm	8	7	**5**	6	9

3.3 Result of Data

The chart in figure 6 illustrates the smoke opacity percentages for various fuel emulsions Diesel, E8, E10, E12, and E15 measured at different engine speeds ranging from 800 to 2,000 rpm. Smoke opacity serves as an indicator of the amount of smoke produced during combustion, where lower values represent cleaner combustion and fewer emissions. Across all engine speeds, the E10 emulsion consistently exhibits the lowest smoke opacity compared to the other emulsions and pure diesel. For instance, at 800 rpm, E10 records a smoke opacity of 7%, which is notably lower than diesel at 10% and E15 at 11%. This trend continues through higher engine speeds, with E10 maintaining lower opacity values even at 2,000 rpm, where it achieves the lowest reading of 5%.

The superior performance of the E10 emulsion can be attributed to its optimal water content. Water emulsions improve combustion efficiency by promoting micro-explosions during fuel combustion, which enhance fuel atomization and mixing with air. This process results in more complete combustion and reduces soot formation, leading to lower smoke emissions. While emulsions with higher water content, such as E15, may introduce combustion instability and incomplete burning, and those with lower water content like E8 or diesel may not provide sufficient improvement, E10 strikes the best balance. Its water ratio effectively stabilizes combustion and minimizes smoke output across varying engine speeds, making E10 the most efficient and environmentally friendly fuel emulsion among those tested.

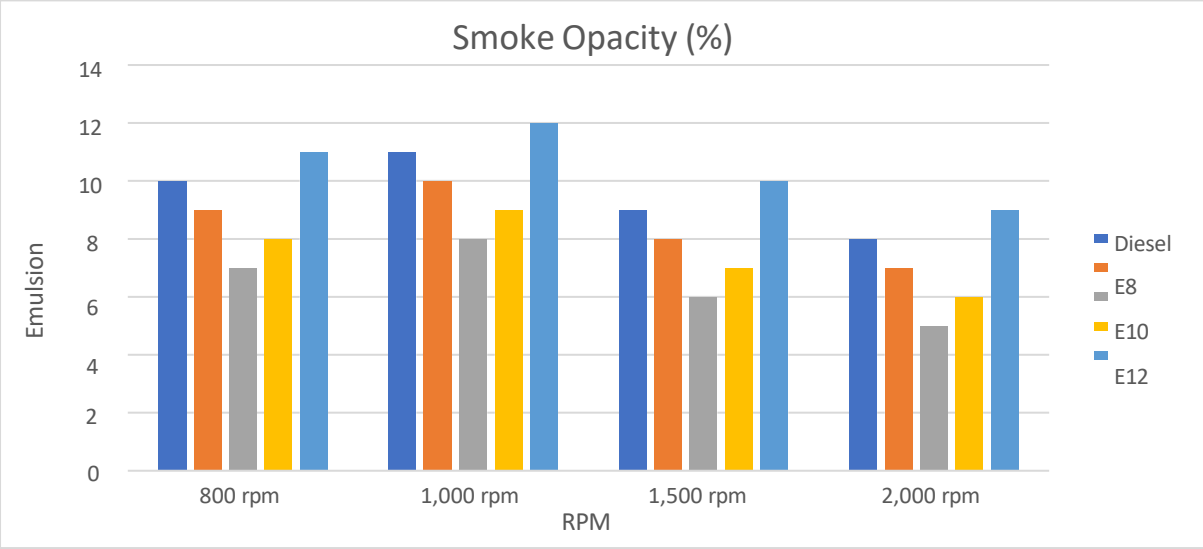

Figure 6: Smoke Opacity for emulsion

4.0 CONCLUSION

This study successfully conducted a series of controlled experiments measuring smoke opacity using a smoke analyzer for pure diesel and diesel-water emulsions with water contents ranging from 8% to 15%. The data obtained allowed for a comprehensive comparison between pure diesel and various emulsified fuels. The results demonstrated that pure diesel generally produced the lowest smoke opacity values across all tested engine speeds. However, among the emulsified fuels, the diesel-water emulsion containing 10% water (E10) exhibited the best performance, with smoke opacity values closest to those of pure diesel, particularly at higher engine speeds. Emulsions with higher water content beyond 10%, such as 12% and 15%, showed increased smoke opacity, indicating less stable combustion and higher particulate emissions. These findings highlight the potential of optimized diesel-water emulsions, especially at 10% water content, to reduce smoke emissions while maintaining combustion efficiency.

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