POLITEKNIK UNGKU OMAR

REBAR INSPECTION USING AUGMENTED REALITY APPLICATION

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(01BCT20F3001)

CIVIL ENGINEERING DEPARTMENT

SESSION 2 2022/2023

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A report submitted in partial fulfilment of the requirements for the award in Bachelor of Civil Engineering Technology with Honours.

CIVIL ENGINEERING DEPARTMENT

SESSION 2 2022/2023

DECLARATION OF ORIGINAL AND OWNERSHIP

TITLE: REBAR INSPECTION USING AUGMENTED REALITY APPLICATION

SESSION: SESSION 2 2022/2023

1. PHOEBE ANAK DANNY (01BCT20F3001)

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In front of me, SUPERVISOR NAME

as project supervisor on date: …….

……
TS. DR. RUFAIZAL BIN CHE MAMAT

APPRECIATION

I would like to express my heartfelt gratitude to God for His blessings and guidance throughout the completion of my Final Year Project, "Rebar Inspection Using Augmented Reality Application." It is by His grace that I have been able to complete this report.

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Thank you.

ABSTRAK

Industri pembinaan adalah salah satu sektor yang paling penting di Malaysia, khususnya dari segi sumbangannya kepada Keluaran Dalam Negara Kasar (KDNK) Malaysia dan pemudahan industri lain untuk meningkatkan hasil produktiviti mereka dengan membina bangunan dan kemudahan untuk mereka. Bagaimanapun, proses pembinaan bangunan dan kemudahan akan mengambil masa yang lama jika dilakukan mengikut amalan konvensional. Disebabkan oleh keadaan ini, penubuhan Objek Rangkaian Internet (ORI) dalam pembangunan pembinaan adalah bermanfaat untuk meningkatkan tahap produktiviti dan mengurangkan masa pembinaan serta kos. Oleh itu. tujuan kajian ini adalah untuk mewujudkan Pemeriksaan Rebar Menggunakan Aplikasi Augmented Reality. Pemeriksaan Rebar Menggunakan Aplikasi Augmented Reality telah dibuat menggunakan alat BlippAR. Menggunakan tinjauan dalam talian yang diubah suai daripada soal selidik Model Penerimaan Teknologi (TAM), yang merangkumi empat pembolehubah TAM yang paling terkenal—kebolehgunaan yang dirasakan, kebergunaan yang dirasakan, sikap terhadap penggunaan teknologi dan niat tingkah laku untuk digunakan—aplikasi ini dinilai untuk kebolehgunaan dan keberkesanan oleh kakitangan syarikat. Ujian-T berpasangan dan min digunakan untuk menganalisis data. Keputusan ujian-t berpasangan menunjukkan bahawa Pemeriksaan Rebar Menggunakan Aplikasi Realiti Diperkukuh berbeza dengan ketara daripada pendekatan semasa. Ini menunjukkan bahawa, jika dibandingkan dengan cara semasa, Pemeriksaan Rebar Menggunakan Aplikasi Realiti Tertambah adalah lebih berkesan dari segi kebolehgunaan. Adalah dinasihatkan untuk menggunakan perisian ini untuk mengurus penyelarasan berkesan orang dan prosedur dalam projek pembinaan.

Kata Kunci: Konvensional, Objek Rangkaian Internet (ORI), BlippAR, Mod Penerimaan Teknologi

ABSTRACT

The construction industry is one of the most significant sectors in Malaysia, specifically in terms of its contribution to the Malaysian Gross Domestic Product (GDP) and facilitation of other industries to enhance their productivity outcome by constructing buildings and facilities for them. However, the process of constructing buildings and facilities will take a long period of time if done according to conventional practices. Due to this circumstance, the establishment of the Internet of Things (IoT) in construction development is beneficial to improve productivity levels and reduce the construction time as well as the cost. Hence. the purpose of this study was to create Rebar Inspection Using Augmented Reality Application. The Rebar Inspection Using Augmented Reality Application was created using the BlippAR tool. Using an online survey modified from the Technology Acceptance Model (TAM) questionnaire, which includes four of the most well-known TAM variables—perceived usability, perceived usefulness, attitude towards using technology, and behavioral intention to use—this application was evaluated for usability and effectiveness by the company's staff. Paired T-Test and mean were used to analyze the data. The results of the paired t-test demonstrated that the Rebar Inspection Using Augmented Reality Application differs significantly from the current approach. This indicates that, when compared to the current way, the Rebar Inspection Using Augmented Reality Application was more effective in terms of usability. It was strongly advised to use this software to manage the effective coordination of people and procedures inside a construction project.

Keywords: Conventional, Internet of Things (IoT), BlippAR, Technology Acceptance Mode

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LIST OF ABBREVIATION

CIDB	Construction Industry Development Board

CHAPTER 1

INTRODUCTION

1.1 Introduction

Civil engineering technicians and technologists work with civil engineers to help plan, design, and build infrastructure and development projects. Civil engineering technicians can advance their careers by learning how to design systems for a variety of projects, such as storm sewer and sanitary systems, as well as traffic light systems. Civil engineers should also be able to comprehend plans and profiles, which are graphical representations of upcoming projects.

Civil engineering technologists' job responsibilities include determining structure sizes, reading, and analyzing project drawings and blueprints, consulting engineers for assistance in drafting plans, engineers supervising the use of computer-aided design tools, examining field conditions prior to construction, observing construction sites, and assessing contractors' work to identify design flaws. Prepare reports, keep track of project data and activities, and create and maintain project files and records. Civil engineering technicians often work under the direction of certified civil engineers. These specialists support civil engineers by monitoring jobsite progress, collecting data, and generating periodical reports to track project

activities. Because civil engineering technicians are not licensed, they cannot approve designs or supervise the entire project.

In a perfect world, quality control or inspection to assure compliance with project drawings, project specifications, material standards, and building codes would not be necessary since the project drawings and project specifications would be complete without errors or omissions, the materials would be manufactured exactly to the material standards, and the field workmanship would be precise. However, in the real world, quality control programs are recommended with inspection usually mandated to ensure compliance with a regulatory agency's policies. (Harsha Slhankarrao Khode, 2019) stated that inspection of the reinforcing bars installed in the forms is done by visual examination of the layout pattern, and by measurement of spacing and counting of bars. The bar diameter and the bar shape, if bent, can be visually checked. Bar lengths, bar spacing's, embedment's, and bearings on walls or beams are normally checked by measurement. In a slab, the total number of pieces can be counted with the spacing of the slab bars verified by measurement, all checked against the approved placing drawings in conjunction with the structural drawings. Similarly, beam longitudinal bars, column vertical bars, and stirrup and tie spacing's are checked visually and by measurement, as required.

Project management has evolved to plan, coordinate, and control the complex and diverse activities of modern industrial, commercial, and management change, as well as information technology (IT) projects (Badiru, 2008). All projects have one thing in common: the transformation of ideas and activities into new ventures. Because of the ever-present element of risk and uncertainty, the events and tasks leading up to completion can never be predicted with absolute certainty. There are numerous examples of projects that have vastly exceeded their budgets, finished late, or even been abandoned before completion. Such failures are all too common in all types of projects in industry, commerce, and (apparently, especially) the public sector.

This proposal contains five chapters, chapter 1, for introduction that will explain or describe the beginning of the chapter, such as problem statement, objective, the scope of the study, the significance of the study, expected outcome, and conclusion. Besides, chapter 2 is a literature review that will explain the study that has a connection with this project.

Meanwhile, chapter 3 is a methodology that contains the method used when ongoing this study. Chapter 4 will describe the result of this project, and chapter 5 will explain the discussion, conclusion, and suggestion. Chapter 1 will be focusing on solving the problem or issues in the construction site, especially regarding the management issues in the area. This study will focus on inspection work for reinforcement bar in site construction due to the issues detected in the company placed for the WBL programme. The issues that had been seen are the inefficient way to do inspection work in the site because those method are not effective to ensure the quality of work in construction. The issues will be solved by creating an application to analyze and measure the quality of the work. By using this application, it will make project engineer, site supervisor and inspector of work works easier.

1.2 Problem Statement

A construction project might run into a lot of difficulties. It is the responsibility of project managers to maintain a site's quality, efficiency, safety, timeliness, and budget. This request can be very challenging at times. Establishing a precise management approach and implementing a comprehensive management system that emphasizes progress, safety, quality, cost, and other aspects is crucial during building construction projects. In addition, process supervision should be strengthened to ensure that the project adheres to established standards. To achieve this, construction personnel must perform a scientific analysis of the overall construction objectives, establish, and enhance the bidding management mechanism during the design phase, and select top-tier suppliers. In preparation for a construction project, it is essential to conduct a thorough evaluation of the construction design, analyzing the construction site environment and relevant data, and meticulously examine all aspects of the construction process using the appropriate data models. These steps are necessary to formulate a comprehensive design and organizational plan. Throughout the construction process, cost control is critical, and the management of materials, equipment, and personnel at all stages must be closely monitored, including pre-construction, construction, and completion. In addition, the budget must be implemented and evaluated quantitatively to ensure that it meets the design requirements, optimize resource allocation, and minimize waste (Ajayi et al., 2017). A serious lack of planning is one of the most frequent problems

contractors have when starting a site preparation project. The inclination, terrain, and general land arrangement differ from site to site. No matter how skilled a professional, every preparation work will inevitably create different difficulties. Poor planning directly leads to inefficiencies. There is an issue if the contractor you employ merely shows up on site and wants to get started right immediately, even if they have a team of experts dressed in identical uniforms. The right team will want to come out and provide some form of analysis if you engage them. They will not just show up and start setting up the site because they cannot determine which machines will function best or what strategy will work best prior to looking at the location.

Ineffective site management may cause project delays and slower growth. Regardless of how difficult the project is, delays happen in majority of construction projects. Delay in construction projects is the lengthening of the project's completion time. In other terms, a delay is when a project isn't finished on schedule and within the allocated money, as specified in the contract (Dulaimi et al., 2003). In this problem statement shows a problem that often occurs in construction which is delay is a big common issue that often happens in works on construction sites in any project across the country. The importance of delay in construction projects and the factors affecting delay are explored by many researchers in the past. The author was reviewed and described those 25 recent articles and based on the review, identified most important factors that are affecting delay in construction comes from small issues and poor administration (He et al., 2020). One of the major challenges faced in construction projects is the improper installation of rebars, leading to wastage of time for engineers. This issue becomes even more difficult when specific zoning requirements are necessary for casting on a given day, compounded by limited knowledge and manpower. The utilization of poor construction practices on construction sites has a detrimental impact on the quality of the concrete produced. To address this problem, it is essential to establish effective guidelines for controlling these practices and ensuring proper construction standards are followed. A wide variety of poor construction practices, resulting from bad workmanship and inadequate quality control and supervision, which lead to many troubles in production and performance of concrete, can be categorized as under (Surahyo, 2019). Many engineering structures must be inspected or monitored throughout their serviceable life to ensure their safe operation. In the case of reinforced concrete structures, the most common

cause of premature failure is corrosion of the steel reinforcement bars that must be pre-empted (Masri et al., 2017). The arrangement effect of bar reinforcement to deformations and cracking behavior of concrete elements subjected to short term loading especially on slab, beam, and column (Rimkus, 2018).

Researchers have made several solutions to the issues that contribute to inefficiencies, which have caused numerous issues for both contractors and other parties. Effective material management is crucial in construction projects as it can lead to cost savings and improved quality. To enhance material management in construction, measures such as controlling material prices, prohibiting shoddy work, implementing a robust purchasing process, creating a scientific purchase plan, and ensuring the purchased materials meet quality requirements are necessary. These actions can help minimize construction costs and improve construction quality (Lima et al., 2021). Afterwards, in Malaysia some project construction management in terms of aspect time, cost, quality, and project scope are the main determinants of project success. Because they lacked effective management at the time, majority of projects in the past had trouble with those essential indicators in finishing a project within the time frame stated with a constrained budget.

Poor detailing of rebar work was found to be an important cause of variation in concrete cover thickness. This type of error is attributed to faulty design, for example, insufficient provision of details regarding steel bending or required concrete cover (Katz, 2018), that leads to rebar placement according to the steel-placer's best judgment. These issues happened in our site which is at Sunway Belfield Project. However, there are a lot of solution that has been made for these issues. For example, (Katz, 2018) investigated the accuracy of steelworks in walls and columns and stated that poor detailing and poor inspection attributed to this poor detailing of rebar works. The inspection work that has been done also require a lot of paper work and this cause the usage of paper in construction work increases every day. According to the Paperless Project, "the average office worker continues to use a staggering 10,000 sheets of copy paper every year," despite digital technology that, in theory, would facilitate offices going paperless. No conversation about sustainability in the office can be complete without discussing paper waste. Engineers doing inspection by referring to a lot of drawings and makes them take quite a time to read and understand the detailing in a drawing. Therefore, the purpose of this study is to produce an application for inspection.

Table 1.1 Research Finding on IOT

Authors (Year)	Findings	Remarks (Strength/Weakness)
(Surahyo, 2019)A.	Improper placement of reinforcement bar	i. Reduce the strength and life of structure ii. Structure failure
(Harsha Slhankarrao Khode, 2019)	Inspection of rebar is done by visual examination of the layout pattern	i. Some misplacement will occur
(Masri et al., 2017)	Damaged steel reinforced on beam	i. Premature failure in beam
(Rimkus, 2018)	Reinforcement layout plays an important role in deformations and cracking performance of the concrete elements.	i. Effect the bond stress on the cover thickness and deformation range of the reinforcement
(Katz, 2018)	Rebar placement and its effect on service life	i. Poor detailing of rebar work was found to be an important cause of variation in cover concrete thickness
(Liu et al., 2021)	Improper rebar layout in reinforced concrete.	i. Resulting higher labour cost, low efficiency, and low accuracy.

Nowadays, the construction industry has been focusing on the concept of the Industrial Revolution (IR) which has become a central topic in recent times. The term 'Industrial Revolution' was coined by the founder and executive chairman of the World Economic Forum, who defined it as a shift from traditional methods to modern ones, incorporating advanced or smart technologies to enhance productivity to its maximum potential (Davis, 2016). The Fourth Industrial Revolution is an extension of the Third Revolution, which introduced computers and automation during its course (M. Xu et al., 2018). The primary focus of the Fourth Industrial Revolution lies in digitalization, which is achieved through the implementation of Cyber-physical Systems, Internet of Things (IoT), and networking. This

transformative process is supported by nine key pillars: advanced robotics, additive manufacturing, augmented reality, simulation, system integration, IoT, cloud computing, cyber-security, and big data analytics. The integration of these pillars has brought about significant changes in the construction industry, enabling more efficient and effective management and control of the entire construction process. Each industrial revolution has had socio-economic implications for various industries, including both positive and negative effects. In the construction industry specifically, the adoption of smart and digital technologies has yielded positive outcomes, leading to improved project performance and increased productivity. These technologies have helped in saving construction time, reducing costs, minimizing defects or clashes, improving construction quality (including safety and client satisfaction), and streamlining the project management lifecycle. Building Information Modelling (BIM) is an example of a smart technology that has played a crucial role in these positive impacts (Mannino et al., 2021).

Although with the IoT application, product development is easier to handle because the entire project progress is digitally tracked through the visualization of the 2D & 3D model. Project management can better utilize project resources, monitor project progress, identify faults and conflicts sooner, give real-time reporting, and control project scheduling and expenses thanks to the digitalization of 3D models. However, not many of the researchers involved in the early studies used BlippAR App in their progress work. Therefore, the purpose of this study is to develop Rebar Inspection Using Augmented Reality Application using BlippAR Application that can help and easier to conduct the work.

1.3 Objectives

In terms of planning for construction stage, the goal of this project is to offer a better project management solution. With the use of just a mobile application, this system enables engineers, site supervisor, consultant, and sub-contractor to access all information about the reinforcement bar at anytime and anywhere. The specified objective includes:

i. To identify application of beam reinforcement bar information and details that can allows users to access information on the details of reinforcement bar.
ii. To develop a rebar inspection of beam application using the Augmented Reality Application.
iii. To validate the effectiveness of Augmented Reality application for inspection work in construction.

1.4 Scope of Study

The Sunway Belfield Project consists of three high-rise buildings divided into three zones: A, B, and C. Figure 1.1 illustrates the location of the project site, while Figure 1.2 depicts the zoning areas for each tower. The project engineers, acting as Block Masters, are responsible for generating daily reports to be submitted to the office and maintained as data for the planner engineer. This study specifically focuses on the inspection work conducted by engineers on the rebar. To streamline the inspection process, an application will be developed to provide engineers with quick access to rebar data and its placement, making inspections more convenient. By utilizing the stored data in the database, analysis of the information becomes much more manageable.

Figure 1.1 The Location of Sunway Belfield

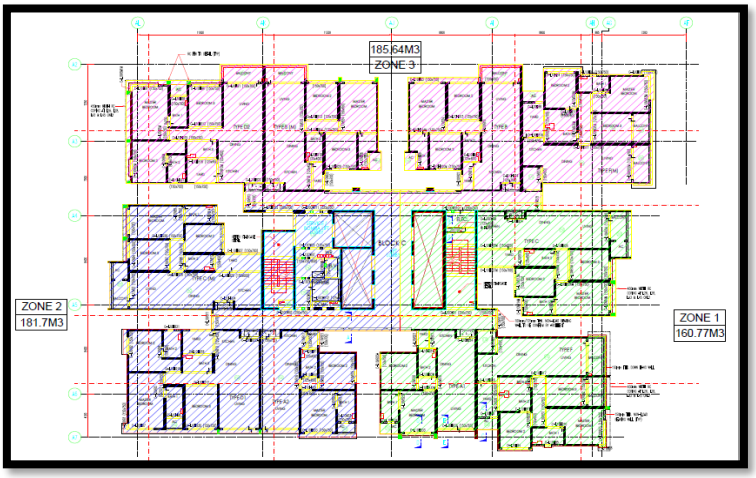


Figure 1.2 The Zoning Area

1.5 Significant of Study

According to the study, one of the common mistakes made by management is a lack of planning. To address this issue, the implementation of an augmented reality application for rebar inspection can greatly assist project managers and engineers in accessing information anytime and anywhere within the project location, specifically for inspection tasks. This application provides users with easy access to detailed project information.

Furthermore, this application will enable project managers, engineers, and other stakeholders to gather essential details regarding rebar, particularly in beam reinforcement. By utilizing this application, valuable time can be saved, and project delays can be avoided as all reinforcement bar details can be thoroughly studied in advance. Moreover, users of this application can ensure the precise execution of required tasks, as it facilitates easy access to work results on the construction site.

1.6 Expected Outcomes

The primary objective of this study is to develop an application that streamlines and enhances the inspection and job processes for site engineers, site supervisors, and work inspectors. The application will primarily focus on analyzing information and details pertaining to reinforcement bars. Users, including site engineers and project engineers, will utilize the application to gather relevant data and information.

To automate and streamline the data collection process, IoT-based inspection systems will be implemented. This technological advancement eliminates the need for manual data recording, reducing the time and effort required for inspections. As a result, the inspection process becomes more efficient, leading to faster turnaround times and improved identification of potential issues.

The integration of IoT technologies allows for remote monitoring of reinforcement bars, enabling inspectors and engineers to access real-time data from any location. This remote accessibility enables prompt actions to be taken in response to critical events or abnormal conditions. Stakeholders can set up alerts and notifications to ensure timely risk mitigation measures and ensure the safety of the structure.

Furthermore, the application not only contributes to sustainability efforts but also introduces companies to the principles of Industry 4.0. By encouraging the use of digital applications instead of traditional paper-based methods, the application promotes the adoption of digital practices and prepares companies for the era of technological advancements.

In summary, this study aims to develop an application that simplifies and enhances the inspection and job processes for site engineers, site supervisors, and work inspectors. Through the implementation of IoT-based inspection systems and remote monitoring capabilities, the application improves efficiency, facilitates prompt actions, and supports the transition to digital practices in line with the principles of Industry 4.0.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The construction industry has seen the evolution of Building Information Modelling (BIM) into a vital digital tool. Concurrently, advancements in Artificial Intelligence (AI) have enabled effective handling of extensive data in complex and uncertain scenarios. The combination of BIM and AI can enhance construction management and add value. The concept of production planning is being considered in construction since Koskela pointed out the importance of the flow and value production as impartible components of the production system. The production system is defined as a set of resources, such as labour, equipment, tools, and information, defined for the design and production of a product (goods or services) that is valuable to customers (Abd Jamil & Fathi, 2020). The construction industry is therefore exposed to greater risks in comparison with other industries due to their unique features such as long project durations, complicated processes, financial intensity, environment constraints and dynamic organization structures. As a result of this, many constructions work in Malaysia consists of a high-risk process that requires a proper follow-up operation involving supervision, implementations, and project completion. These risks are

generally considered as incidences that influence the principal objectives of a particular project such as the time, cost and quality as reported by (Badiru, 2008).

The construction industry has been the subject of academic research, but most studies focus on technology-driven design rather than product demand. This lack of research can impact consumer demand and hinder industry growth, which has been performing worse than the overall economy during recessions. Understanding the correlation between economic growth and the construction industry's output components, including commercial, residential, and civil engineering, is critical. The construction industry is a significant economic sector, involving large investments, high costs, and multiple components. Therefore, conducting a demand analysis for each product type is essential to determine the economic impact on Malaysia's construction sector. A thorough investigation of the industry's development trends is necessary to plan and organize systematically and proactively to face the industry's challenges during a recession.

Nevertheless, a nation that is at the vanguard of developed nations is greatly impacted by new technology. Make use of Malaysian development construction technology to simplify all the work that has to be done. It is still possible to minimize the use of conventional construction methods in this technological area. As a result, the use of technology in the construction industry will be advantageous because it can increase productivity and save time. Furthermore, it can be used anywhere and makes daily work easier with the touch of a finger thanks to innovations like applications or software systems. To identify current research knowledge, the researcher will present a summary of the literature on the conclusion of ongoing study in this chapter. Predicting a superior resolution to the issue is also appropriate in addition to the previous point. A better answer for the researcher might come from a prior case study involving the other researcher.

The construction industry has attracted researchers, but most of the studies carried out in the construction industry are based on the study of technology as a design analysis. The lack of study will affect product demand and the development of the construction industry. This is probably one of the causes of surplus output growth falling in the building sector, and the construction industry is worse off than the national economy at a time of economic downturn. The analysis of product demand and the relationship between economic growth and the

construction industry has been shown. Research examines the development of the construction industry and the correlation with the output components to be carried out, such as commercial, residential, and civil engineering. As the construction industry involves investments or high costs and various components, it is often linked to the output of the request. Demand analysis for each type of product development is very important to know the extent of the economic impact on the development of the construction industry in Malaysia. Analyze of the trends in construction industry and its relationship with the demand for its products to be made. This will give a clear picture of the development of the construction industry in the past, but also to estimate its future. The close relationship between the construction industry and the economic growth of a country is often mentioned. The instability of the construction industry in Malaysia has led people to worry about making an investment. A detailed analysis is made to study the development of the construction industry in Malaysia in order to plan and prepare systematically in advance in order to overcome the problem of the construction industry during the recession. As the construction industry as a major economic sector in Malaysia, a detailed study should be made so that its development trends can be identified (Ibrahim et al., 2021).

Nevertheless, new technology also has an exquisite impact on a country in the lead of developed countries. Refer to development construction technology in Malaysia and facilitate all work completed in this development. Even with this technology field, it can minimize conventional use in construction. In this construction sector, therefore, the application of technology will have an advantageous impact in which it can improve efficiency and save time. Moreover, by applying technologies such as apps or software systems, it can be opened anywhere and simplifies everyday work with just a fingertip. In this chapter, the researcher will provide an overview of the literature on the completion of ongoing research to identify current research knowledge. Apart from that, it is also appropriate to predict a better solution to the problem. The researcher could also find a better solution through a previous case study using the other researcher.

The aim of the work reported in this paper was therefore to study the trends, opportunities and challenges involved when developing and using smart applications in the construction sector. A specific goal of the work was to identify and present a comprehensive overview of existing application areas that demonstrate potential to benefit from these technologies.

Although the review was focused on construction, its findings may also apply to the wider context of ‘industry 4·0’ (Lampropoulos et al., 2019), civil engineering, smart homes, cities, communities, transport and similar.

2.2 Construction Technology

The Construction Industry Institute defines construction technology as 'the collection of innovative tools, machines, modifications, software, etc. used during the construction phase of a project that enables advancement in field construction methods, including semi-automated and automated construction equipment' (He et al., 2020).

New construction technologies are currently being developed at a breakneck pace. What appeared to be future tech 10, 20 years ago as connected equipment and tools, telemetric, mobile apps, autonomous heavy equipment, drones, robots, augmented and virtual reality, and 3D printed buildings are here and are being deployed and used on workplaces around the world.

Today there are software and mobile solutions to help manage every aspect of a construction project. From preconstruction to scheduling, from project management and field reporting to managing your back office, there is a software solution out there to help streamline your processes and improve productivity. Most software solutions are cloud-based, allowing changes and updates to documents, schedules, and other management tools to be made in real time, facilitating better communication and collaboration.

Besides, mobile technology allows for real-time data collection and transmission between the jobsite and project managers in the back office. Cloud-based solutions enable on-site employees to submit timecards, expense reports, and requests for information (RFIs), work records, and other verified documentation. This can save hundreds of hours per year in data entry and automatically organizes critical files—no more shuffling through files looking for old reports. More and more software providers are forming strategic partnerships to allow people to seamlessly integrate the data with other software solutions, making it easier than ever to run the business.

2.3 Technology IR 4.0

The Fourth Industrial Revolution, which has often been mentioned now, calls for changes to be made within the construction industry, in tandem with the rapid development of technology and smarter systems. This revolution marks the emergence of a physical cyber system that will change the future of the construction process. Emphasis on the use of technology plus the need to enhance skills and knowledge is a vital basis for dealing with these changes. Significant to the situation, the Ministry of Works/Kementerian Kerja Raya (KKR) through CIDB and in collaboration with stakeholders in the construction industry are amid the development of Construction Strategy Plan 4.0 (2021 – 2050) to help the construction.

Construction Strategy Plan 4.0 is a five-year CIDB short-term plan that will form the basis for a draft plan framework that will boost the capacity of the construction industry in the 4.0 Industrial Revolution. The strategic plan is being developed in line with Shared Prosperity Vision 2030/Wawasan Kemakmuran Bersama (WKB) 2030 and National 4.0 Industry Policy (Industry4WRD)/Dasar Industri 4.0 (Industry4WRD). It also supports and complements other national policies, including the National IoT Strategic Roadmap/Pelan Hala Tuju Strategik Internet of Things (IoT) Kebangsaan, Malaysia Smartcity Framework/ Rangka Kerja Bandar Pintar Malaysia and, Digital Economic Policy/ Dasar Ekonomi Digital.

The Construction Strategy Plan 4.0 has also identified 12 key technologies, also known as 'disruptive technologies,' which will change the future of the construction landscape and which are:

i. Building Information Modeling (BIM)
ii. Pre-fabrication and Modular Construction
iii. Autonomous Construction
iv. Augmented Reality & Virtualization
v. Cloud and Real-time Collaboration
vi. 3D Scanning and Photogrammetric
vii. Big Data & Predictive Analysis
viii. Internet of Things
ix. 3D Printing and Additive Manufacturing

x. Advanced building materials
xi. Block chain
xii. Artificial Intelligence

Complex and dynamic changes are needed in the 4.0 Industrial era in order to be in line with the flow of technological revolution that we will eventually face in the future. The situation calls for effective governance and excellent cooperation between the various parties, including government, industry, academia, and society (Zambon et al., 2019).

2.4 Internet of Things (IoT)

The triumvirate of internet of things (IoT), artificial intelligence (AI) and cloud technologies offers new opportunities for the development of new applications in many industrial domains. It stimulates a new wave of highly dependable, available, reliable, safe, secure, and performing smart applications. These technologies have already been used in parts or jointly to build applications that provide various benefits, such as improved logistics, safety, and security in industrial settings. While smart applications have already been demonstrated in different industrial sectors, there is a general impression that the construction sector is lagging. An initial review of the literature showed a consistent lack of studies involving the joint use of IoT, AI and cloud technologies. Pretz has indicated that the Internet of things (IoT) is a thing connected network, where things are wirelessly connected via smart sensors (Lampropoulos et al., 2019), IoT is able to interact without human intervention. Some preliminary IoT applications have been already developed in healthcare, transportation, and automotive industries. Currently, IoT technologies are at their infant stages; however, many new developments have occurred in the integration of objects with sensors in the cloud-based Internet (Hepp et al., 2006). The development of IoT involves many issues such as infrastructure, communications, interfaces, protocols, and standards. I am motivated to summarize the research progress achieved so far in the development, standardization, and security assurance of IoT enabling technologies, and to identify critical research topics and future research directions of IoT.

2.4.1 The Concept of IoT

Kevin Ashton firstly proposed the concept of IoT in 1999, and he referred the IoT as uniquely identifiable interoperable connected objects with radio-frequency identification (RFID) technology. However, the exact definition of IoT is still in the forming process that is subject to the perspectives taken (Hepp et al., 2006). IoT was generally defined as "dynamic global network infrastructure with self-configuring capabilities based on standards and interoperable communication protocols; physical and virtual 'things' in an IoT have identities and attributes and are capable of using intelligent interfaces and being integrated as an information network" (Y. Li et al., 2012). Basically, the IoT can be treated as a superset of connecting devices that are uniquely identifiable by existing near field communication (NFC) techniques. The words "Internet" and "Things" mean an inter-connected world-wide network based on sensory, communication, networking, and information processing technologies, which might be the new version of information and communications technology (ICT), (Ud Din et al., 2019).

Despite the argument on the definition of IoT, it has been discussed widely and corresponding technologies have been rapidly developed by various institutions (Hepp et al., 2006) in particular, intelligent sensing and wireless communication techniques have become part of the IoT and new challenges and research horizons have emerged (Paul & Jeyaraj, 2019). The International Telecommunication Union (ITU) discussed the enabling technologies, potential markets, and emerging challenges and the implications of the IoT (Wortmann & Flüchter, 2015). The evolvement of IoT can be illustrated by several phases as shown in Figure 2.1.

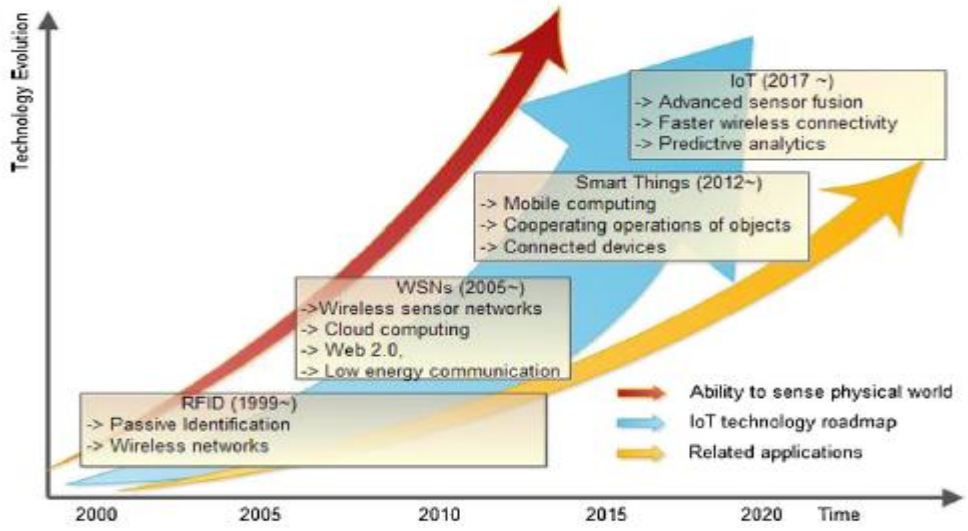


Figure 2.1: The Evolution of the IoT. ***(Source: A survey of Internet of Things,*** (S. Li et al., 2015)

The IoT is initiated using RFID technology, which is increasingly used in logistics, pharmaceutical production, retail, and diverse industries (Al-Fuqaha et al., 2015). The emerging wirelessly sensory technologies have significantly extended the sensory capabilities of devices and therefore the original concept of IoT hence is extending to ambient intelligence and autonomous control. To date, several technologies are involved in IoT, such as wireless sensor networks (WSNs), barcodes, intelligent sensing, RFID, NFC, low energy wireless communications, cloud computing, and so on (C. Z. Li et al., 2018). The IoT describes the next generation of Internet, where the physical things could be accessed and identified through the Internet. Depending on various technologies for the implementation, the definition of the IoT varies. However, the fundamental of IoT implies that objects in an IoT can be identified uniquely in the virtual representations. Within an IoT, all things can exchange data and if needed, process data according to predefined schemes.

2.4.2 Emerging Smart Construction Application

The highlighted improvements in the mainstream ICT area were then linked to a selection of publications addressing construction-related issues in the following phase of the review process. Several possible smart application areas were found, including construction monitoring, construction site management, workplace safety, early warning of accidents, and resource and asset management. A mind map summarizing the identified application areas is shown in Figure 2.2. In the following sub-sections, representative works are presented.

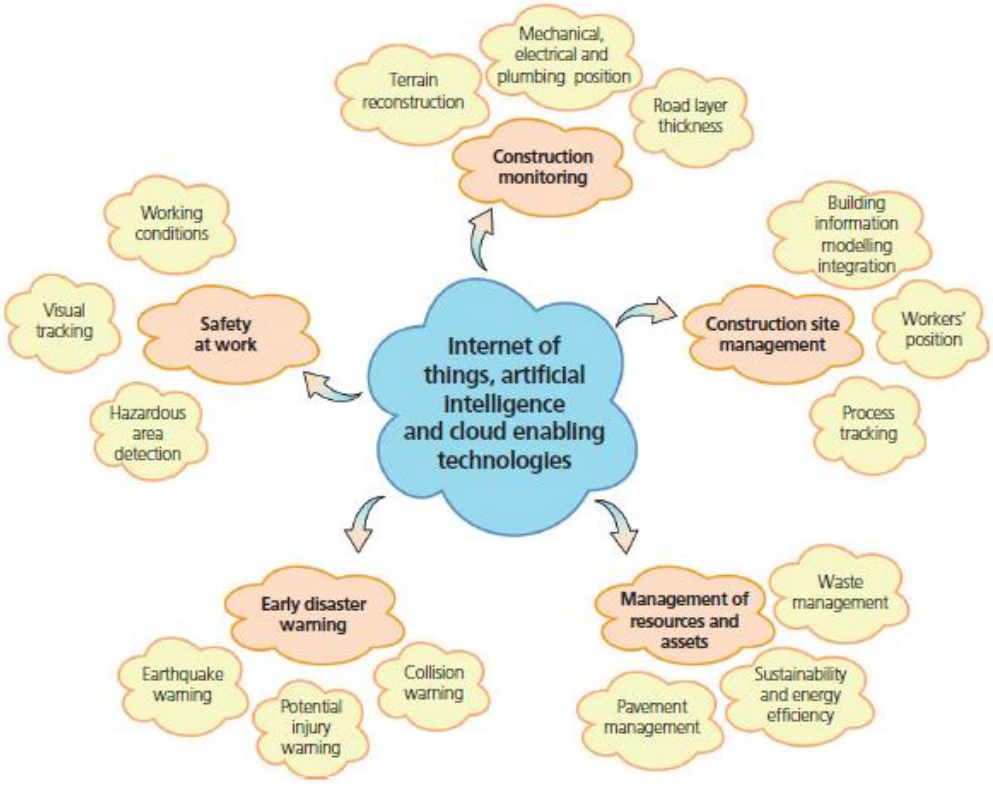


Figure 2.2: Converging internet of things, artificial intelligence, cloud, fog, and edge computing technologies will provide the necessary dependability to time-critical smart construction applications. ***(Source: A review of technologies and applications for smart construction*** (C. Z. Li et al., 2018)***.)***

i. Construction Monitoring

Construction monitoring aims at preventing the occurrence of errors in the stability and durability of the buildings under construction. Only a few relevant applications have been identified, as follows.

An application has been developed to determine the exact position of the arm of a trencher (Lampropoulos et al., 2019). The identified position is used to prevent the tearing of wires, water pipes and gas pipes during operation. The developed algorithm calculates the difference between the existing mechanical, electrical and plumbing (MEP) systems and the intended operation area of the trencher.

One of the aims of the study was to develop a low-cost alternative to existing systems that determine the position of reinforcement bar on slab. Instead of determining the rebar on slab by visual, which are usually embedded in construction practices, this application uses a camera system and reference markers to determine the position of the reinforcement bars. With the current level of technology readiness, this application could be conveniently developed by using IoT and cloud technologies.

Another application (Lin et al., 2015) is used to facilitate automated measurements of the thickness of road layers. Its purpose is to prevent adverse effects on vehicles due to poorly maintained roads. This infrastructure-monitoring application is used to identify such road sections, properly mark them, and use the information for road maintenance and signalization. In the context of ‘big data’ an application like this can be integrated in road network information systems.

Construction vibrators are used widely in construction. They consist of an electric motor with eccentric rotation mass, packed into a hermetically sealed container, which causes vibrations while spinning. They are used to remove packets of air trapped in poured concrete. An envisioned smart application (Štefanič & Stankovski, 2019) uses a real-time wireless-sensing-based internal vibrator tip tracking system that supports intelligent concrete consolidation operations. Using ultra-wideband radio waves, it determines the location of the construction vibrator, which prevents trapped air being missed. Real-time positioning is

achieved through data integration from various sources, such as a combination of video streams and three-dimensional (3D) data visualization.

Video streams coming from stereo cameras have been used for 3D reconstruction of terrain (Harty, 2005). The resulting 3D images have then been used by construction workers to visualize current construction status. This represents a fast and robust 3D terrain-reconstruction system. The algorithms employed to analyze video streams start with the generation of multiscale descriptors (MSD), and continue with a plot consisting of triangles. The product of the application is a 3D real-time terrain reconstruction, which has the potential to become an integral part of many high-tech solutions in the construction industry.

ii. Construction Progress Tracking

Numerous studies on construction site management have been conducted. In general, their purpose is to gain a thorough understanding of existing building processes while lowering the amount of time, subjectivity, and mistakes caused by physical labor. A collection of such works is shown below.

An application automatically compares the state of a construction with its plan based on stereo photogrammetry (Braun & Borrmann, 2019). The collected data represent a dense point cloud. This requires the fusion of disparity maps created with semiglobal matching (SGM) with the target state provided by a four-dimensional (4D) building information model. An application like this requires the integration of various cameras with software tools, such as building information modelling (BIM) tools, which can be achieved seamlessly through the usage of cloud technology.

An application has been developed for tracking, analysis, and visualization of as-built status of buildings under construction, and comparison against a 4D BIM model (Schiavi et al., 2021). Photographs taken daily from the construction site are used as input to the application. This application type is suitable for the use of AI methods such as TensorFlow.

Another application is used for progress tracking at construction sites (Ahmed, 2019). 3D object models are built by using a 3D laser scanner. These are then combined with a 4D object-oriented progress-tracking system. The application demonstrates a high degree of accuracy for automated progress tracking that meets or exceeds typical manual performance.

Additional integration with other data sources may contribute to even higher accuracy of the application.

Construction progress can be recorded in 4D computer-aided design (CAD) models, which may be updated timely and accurately during construction. This makes it possible to align progress with schedule (Rankohi & Waugh, 2013).

Video analysis can be used to determine workers' positions from video clips (Tang et al., 2020). The application does not require any additional equipment for the tracking. The analysis of the video is sufficient since specifically implemented algorithms recognize movements, shape, and color. The application can be used for, but is not limited to, measuring productivity of workers, analyzing the sequence of activities, and improving site safety. Dependability is obviously an important property of applications such as this one, which must be obtained when realizing the same software service by way of the cloud. This, however, is a nontrivial problem in the cloud computing domain.

2.4.3 IoT Elements

Understanding the IoT building blocks helps to gain a better insight into the real meaning and functionality of the IoT. In the following sections we discuss six main elements needed to deliver the functionality of the IoT as illustrated in Figure 2.3. Table 2.1 shows the categories of these elements and examples of each category.

Figure 2.3: Elements of IoT ***(Source: Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications*** (Al-Fuqaha et al., 2015)

i. Identification

Identification is crucial for the IoT to name and match services with their demand. Many identification methods are available for the IoT such as electronic product codes (EPC) and ubiquitous codes (uCode) (Deepika et al., 2021). Furthermore, addressing the IoT objects is critical to differentiate between object ID and its address. Object ID refers to its name such as “T1” for a particular temperature sensor and object’s address refers to its address within a communications network. Distinguishing between object’s identification and address is imperative since identification methods are not globally unique, so addressing assists to uniquely identify objects. In addition, objects within the network might use public Ips and not private ones. Identification methods are used to provide a clear identity for each object within the network.

ii. Sensing

The IoT sensing means gathering data from related objects within the network and sending it back to a data warehouse, database, or cloud. The collected data is analyzed to take specific actions based on required services. The IoT sensors can be smart sensors, actuators, or wearable sensing devices. For example, companies like Wemo, revolve and SmartThings offer smart hubs and mobile applications that enable people to monitor and control thousands of smart devices and appliances inside buildings using their smartphones (Deepika et al., 2021).

iii. Communication

Internet of Things (IoT) devices communicate is dozens of different ways, using hundreds of different protocols. That is because how they communicate depends on what they are, where they are, what other devices and systems they need to talk to, and what they have to say. There is no single best protocol, which is essentially the common "language" used to route messages from one IoT device to another. The right choice always depends on the application’s specific needs (Akinlabi et al., 2021).

The IoT communication technologies connect heterogeneous objects together to deliver specific smart services. Typically, the IoT nodes should operate using low power in the presence of lossy and noisy communication links. Examples of communication protocols used for the IoT are Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, and LTE-Advanced. Some specific communication technologies are also in use like RFID, Near Field Communication (NFC) and ultra-wide bandwidth (UWB). RFID is the first technology used to realize the M2M concept (RFID tag and reader). Some specific communication technologies are also in use like RFID, Near Field Communication (NFC) and ultra-wide bandwidth (UWB). RFID is the first technology used to realize the M2M concept (RFID tag and reader). The RFID tag represents a simple chip or label attached to provide object's identity. The RFID reader transmits a query signal to the tag and receives reflected signal from the tag, which in turn is passed to the database. The database connects to a processing center to identify objects based on the reflected signals within a (10 cm to 200 m) range (Lombardi et al., 2021). RFID tags can be active, passive, or semi-passive/active. Active tags are powered by battery while passive ones do not need battery. Semi-passive/active tags use board power when needed.

Another communication technology is Wi-Fi that uses radio waves to exchange data amongst things within 100 m range (Lombardi et al., 2021). Wi-Fi allows smart devices to communicate and exchange information without using a router in some ad hoc configurations. Bluetooth presents a communication technology that is used to exchange data between devices over short distances using short-wavelength radio to minimize power consumption (Silva et al., 2018).

iv. Services

Overall, IoT services can be categorized under four classes (Al-Fuqaha et al., 2015), which are Identity-related Services, Information Aggregation Services, Collaborative-Aware Services and Ubiquitous Services. Identity-related services are the most basic and important services that are used in other types of services. Every application that needs to bring real world objects to the virtual world must identify those objects. Information Aggregation Services collect and summarize raw sensory measurements that need to be processed and reported to the IoT application. Collaborative-Aware Services act on top of Information

Aggregation Services and use the obtained data to make decision and react accordingly. Ubiquitous Services, however, aim to provide Collaborative-Aware Services anytime they are needed to anyone who needs them anywhere. With this categorization, view some applications of the IoT in the following paragraphs. The ultimate goal of all IoT applications is to reach the level of ubiquitous services.

Apart from that, industrial automation (Wollschlaeger et al., 2017) is computerizing robotic devices to complete manufacturing tasks with a minimal human involvement. It allows a group of machines to produce products quickly and more accurately based on four elements: transportation, processing, sensing and communication. The IoT is utilized in industrial automation to control and monitor production machines' operations, functionalities, and productivity rate through the Internet. For instance, if a particular production machine encounters a sudden issue, an IoT system sends a maintenance request immediately to the maintenance department to handle the fix. Furthermore, the IoT increases productivity by analyzing production data, timing and causes of production issues.

IoT Elements		Samples
Identification	**Naming**	EPC, uCode
	Addressing	IPv4, IPv6
Sensing		Smart Sensors, Wearable sensing devices, Embedded sensors, Actuators, RFID tag
Communication		RFID, NFC, UWB, Bluetooth, BLE, IEEE 802.15.4, Z-Wave, WiFi, WiFiDirect, , LTE-A
Computation	**Hardware**	SmartThings, Arduino, Phidgets, Intel Galileo, Raspberry Pi, Gadgeteer, BeagleBone, Cubieboard, Smart Phones
	Software	OS (Contiki, TinyOS, LiteOS, Riot OS, Android); Cloud (Nimbits, Hadoop, etc.)
Service		Identity-related (shipping), Information Aggregation (smart grid), Collaborative-Aware (smart home), Ubiquitous (smart city)
Semantic		RDF, OWL, EXI

Table 2.1: Building Blocks and Technologies of the IoT

v. Semantics

Semantic in the IoT refers to the ability to extract knowledge smartly by different machines to provide the required services. Knowledge extraction includes discovering and using resources and modeling information. Also, it includes recognizing and analyzing data to make sense of the right decision to provide the exact service (Paul & Jeyaraj, 2019). Thus, semantic represents the brain of the IoT by sending demands to the right resource.

2.4.4 Big Data Analytics, Cloud and Fog Computing in Support of the IoT

Connecting many physical objects like humans, animals, plants, smart phones, PCs, etc. equipped with sensors to the Internet generates what is called "big data." Big data needs smart and efficient storage. Obviously, connected devices need mechanisms to store, process, and retrieve data. But big data is so huge such that it exceeds the capability of commonly used hardware environments and software tools to capture, manage, and process them within an acceptable slot of time.

Cloud services allow individuals and companies to use remote third-party software and hardware components (Lee & Lee, 2015). Cloud computing enables researchers and businesses to use and maintain many resources remotely, reliably and at a low cost. The IoT employs many embedded devices, like sensors and actuators that generate big data which in turn requires complex computations to extract knowledge (Lampropoulos et al., 2019). Therefore, the storage and computing resources of the cloud present the best choice for the IoT to store and process big data.

i. Big Data Analytics in Support of the IoT

What makes big data an important asset to businesses is that it makes it possible to extract analytics and consequently knowledge, by which a business can achieve competitive advantage. There are some platforms for big data analytics like Apache Hadoop and SciDB. However, these tools are hardly strong enough for big data needs of IoT (Lampropoulos et al., 2019). The amount of IoT data generally is too huge to be fed and processed by the

available tools. In support of the IoT, these platforms should work in real-time to serve the users efficiently. For example, Facebook has used an improved version of Hadoop to analyze billions of messages per day and offer real-time statistics of user actions (Kumari et al., 2018). Instead of providing application specific analytics, IoT needs a common big data analytic platform which can be delivered as a service to IoT applications. Such analytic service should not impose a considerable overhead on the overall IoT ecosystem.

ii. Cloud Computing for IoT

Cloud computing (CC) offers a new management mechanism for big data that enables the processing of data and the extraction of valuable knowledge from it. Employing CC for the IoT is not an easy task due to the following challenges:

i. Synchronization: Synchronization between different cloud vendors present a challenge to provide real-time services since services are built on top of various cloud platforms.
ii. Standardization: Standardizing CC also presents a significant challenge for IoT cloud-based services due having to interoperate with the various vendors.
iii. Balancing: Making a balance between general cloud service environments and IoT requirements presents another challenge due to the differences in infrastructure.
iv. Reliability: Security of IoT cloud-based services presents another challenge due to the differences in the security mechanisms between the IoT devices and the cloud platforms.
v. Management: Managing CC and IoT systems is also a challenging factor since both have different resources and components. Enhancement: Validating IoT cloud-based services is necessary to ensure providing good services that meet the customers' expectations.

IoT can utilize numerous cloud platforms with different capabilities and strengths such as ThingWorx, OpenIoT, Google Cloud, Amazon, GENI, etc. For example, Xively (formerly known as Cosm and Pachube) represents one of the first IoT application hosting service providers allowing sensor data to be available on the web. Xively aims to connect devices to

applications securely in real-time. Xively provides a Platform as a Service (PaaS) solution for the IoT application developers and service providers. It can integrate devices with the platform by ready libraries. It could also integrate with other platforms using Java, JS, Python, and Ruby libraries. The automated parking lot presented is a sample of using Xively to implement IoT applications. Some of the features that made Xively one of the preferred cloud-based service providers for IoT service offerings are:

i. Open source, free and easy to use as it exposes accessible Application Programming Interfaces (APIs).
ii. Interoperability with many protocols, environments, and its ability to manage real-time sensors and distribute data in numerous formats such as JSON, XML and CSV.
iii. Enables users to visualize their data graphically in real-time using a website to monitor activities based on data sensors. Also, it enables users to control sensors remotely by modifying scripts to receive an alert.

Platform	Gateway	Provision	Assurance	Billing	Application Protocol			
					REST	CoAP	XMPP	MQTT
Arkessa	-	+	+	-	+	-	-	+
Axeda	+	+	+	+	+	-	-	-
Etherios	+	+	+	-	+	-	-	-
LittleBits	-	-	-	-	+	-	-	-
NanoService	+	+	+	-	+	+	-	-
Nimbits	-	-	-	-	+	-	+	-
Ninja Blocks	+	-	-	-	+	-	-	-
OnePlatform	+	+	+	-	+	+	+	-
RealTime.io	+	+	-	-	+	-	-	-
SensorCloud	+	+	-	-	+	-	-	-
SmartThings	+	+	-	-	+	-	-	-
TempoDB	-	-	-	-	+	-	-	-
Thingworx	-	+	+	-	+	-	-	+
Xively	+	+	+	+	+	-	-	+

Table 2.2: IoT Cloud Platforms and Their Characteristics. ***(Source:*** (Alptekyn & Alptekin, 2018)***, "A framework for customer-oriented IoT product design" 2018)***

iv. Supported by many Original Equipment Manufacturers (OEM) like Arexx, Nanode, OpenGear, Arduino, and mBed.

Table 2.2 summarizes some characteristics of several publicly available Cloud platforms for IoT (in the table, "+" stands for support and "–" stands for lack of support) (Alptekyn & Alptekin, 2018). The evaluation metrics include: supporting gateway devices to bridging the short-range network and wide area network, supporting discovery, delivery, configuration and activation of applications and services, providing proactive and reactive assurance of platform, support of accounting and billing of applications and services, and finally support of standard application protocols. All the platforms support sensing or actuating devices, a user interface to interact with devices, and a web component to run the business logic of the application on the cloud. Also, none of them supports the DDS protocol.

iii. Fog Computing in Support of IoT

Fog Computing (a.k.a. cloudlets or edge computing) can act as a bridge between smart devices and large-scale cloud computing and storage services. Through fog computing, it is possible to extend cloud computing services to the edge devices of the network. Because of their proximity to the end-users compared to the cloud data-centers, fog computing has the potential to offer services that deliver better delay performance. It should be emphasized here that, typically there is a significant difference in scale between the fog and the cloud such that the cloud has massive computational, storage and communications capabilities compared to the fog (Pan & Zhang, 2021). Figure 2.4 illustrates the roles that the cloud data-centers and the cloudlets (fog computing) play to deliver IoT services to end-users. Mobile network operators are the potential providers of fog computing since they can offer fog services as one of IaaS, PaaS, or SaaS models to the enterprise businesses by providing services at their Service network or even cell tower (Al-Fuqaha et al., 2015).

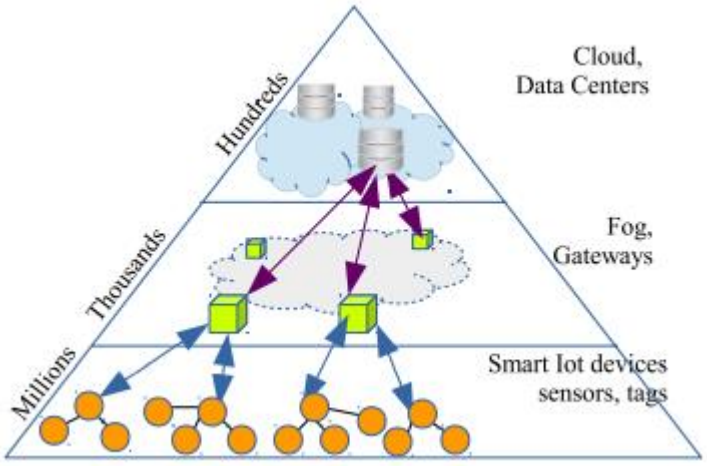


Figure 2.4: The role of the cloud and fog resources in the delivery of IoT services. ***(Source: Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. Ala Al-Fuqaha, 2015)***

Fog computing can serve as an optimal choice for the IoT designers for the following features:

i. Location: Fog resources are positioned between smart objects and the cloud data-centers; thus, providing better delay performance.
ii. Distribution: Since fog computing is based on "micro" centers with limited storage, processing and communication capabilities compared to the cloud, it is possible to deploy many such "micro" centers closer to the end-users as their cost is typically a small fraction compared to cloud data-centers.
iii. Scalability: Fog allows IoT systems to be more scalable such that as the number of end-users increase, the number of deployed "micro" fog centers can increase to cope with the increasing load. Such an increase cannot be achieved by the cloud because the deployment of new data-centers is cost prohibitive.
iv. Density of devices: Fog helps to provide resilient and replicated services. Mobility support: Fog resources act as a "mobile" cloud as it is located close to the end-users.
v. Real-time: Fog has the potential to provide better performance for real-time interactive services. Standardization: Fog resources can interoperate with various cloud provides.

vi. On the fly analysis: Fog resources can perform data aggregation to send partially processed data as opposed to raw data to the cloud data-centers for further processing.

Therefore, fog computing has the potential to increase the overall performance of IoT applications as it tries to perform part of high-level services which are offered by cloud inside the local resources.

v. Mobile Phone for Supporting IoT

A mobile device (e.g., tablet or laptop) is a portable device with an operating system (OS) that can run applications, such as business, enterprise resource-planning, and finance applications. Most portable devices are equipped with Wi-Fi, Bluetooth, Near-Field Communication (NFC), and Global Positioning System (GPS) capabilities that allow connections to the Internet and other devices. Mobile devices can also be used to provide location-based services (Abbas et al., 2020). Smartphones and personal digital assistants are suitable for users who want to utilize some of the conveniences of a traditional PC at a location where moving one would be impractical. Digital business partners can further enhance the accessible components for business users by integrating data capture devices, such as barcode, RFID, and smart card readers (Rajeswari & Anbalagan, 2020). Nevertheless, mobile devices are vulnerable to threats and attacks, such as tracking, corruption, and deletion.

vi. Internet

The Internet is the global arrangement of interconnected computers that uses the traditional Internet protocol (IP) suite (TCP/IP) to connect billions of devices globally. This arrangement consists of a network of networks, such as private, public, academic, business, and government networks, from a local to a worldwide scope that are connected by an extensive collection of electronic, wireless, and optical networking technologies. A broad range of information and services are provided by the Internet, such as the connection between hypertext files and the World Wide Web application, e-mail, communication, and distributed systems for document sharing (Mahmud et al., 2018). The Internet communication

framework consists of hardware components and software layers that control various aspects of the framework. The Internet serves as a platform for millions of constrained devices connected to communicate and share resources (Alaba et al., 2017). However, the Internet is exposed to several common security and privacy challenges, such as confidentiality encryption, viruses, cyberbullying, hacking, identity theft, reliability, integrity, and consent.

vii. Sensor Gateway

Sensor gateways deal with wireless network and collective data from various distributed WSN nodes. Every gateway includes a 2.4 GHz IEEE 802.15.4 radio for communication. WSN involves the collection of dedicated transducers with a communication framework for checking and recording the conditions of any sensor device at different positions/locations. The following parameters are checked regularly: temperature, humidity, pressure, wind direction and speed, light strength, vibration strength, sound strength, power-line voltage, chemical concentrations, pollutant levels, and dynamic body functions. The wireless communication channel involves radio communication, transmitters, and receivers for the data exchange between two or more devices. This channel enhances user access, network expansion, mobility, and collaboration. Nevertheless, this channel leads to several threats and attacks, such as misconfiguration, hacking, signal lost, DoS, war dialing, protocol tunneling, man-in-the-middle attack, interruption interception, and modification fabrication (Y. Li et al., 2012). Table 2.3 compares the IoT communication channels from a security perspective with focus on the most common technologies used in the IoT, such as RFID, sensor nodes, and sensor gateways.

Table 2.3: Comparison of IoT communication channel regarding security

Type of Security	RFID	Sensor Nodes	Sensor Gateway
Encryption	Weak	Fair	None
Authentication	Fair	Strong	Strong
Authorization	Fair	Strong	Strong
Privacy	Fair	Fair	Weak

2.5 Challenges of Implementing IoT in Construction Projects

IOT has been extensively applied in different fields such as consumers, commercial and infrastructure (Lee & Lee, 2015). In the construction sector, it is difficult to adopt and embrace new technology because of the complexity of construction projects and the high risks of failure, which constrains the application. Despite all these difficulties, IOT has been used in the construction industry, and one of the leading applications are monitoring and controlling of project executions in a different type of projects such as bridges, railways, tunnels, onshore and offshore facilities (Ghimire et al., 2017). Further, it has been used to monitor building performance during disasters, real-time safety warnings and risk detections. Chandanshive and Kazi (2017) investigated the wide range of IOT applications in construction, which includes the design of smart cities, smart dwelling and smart transportation. The BIM engineering US (2018) highlighted the most widespread applications of IOT in the construction industry as follows:

i. Preventive Maintenance: This is important for machineries on site where any breakdown is monitored by the embedded system and sensor in the machine to report any need of fix that requires maintenance.
ii. Reduction Of Admin Expenditure: By offering data driven choice that helps to produce accurate forecast whereby the data are used to make fast and precise decisions
iii. Real Time Monitoring and Observation: The information attained from sensors and embedded systems can be used to monitor the process of construction and that also helps to produce accurate decision.
iv. Construction Management: IOT helps to avoid downtime and helps to provide advanced communication with all things such as materials and trucks by helping decisions makers to cut back the cost overrun that incurred because of the excessive use of materials and machinery.
v. Human Resource Monitoring: IOT helps tracking the labor hours estimated for any assignments. Safety On Site: IOT helps to track labor on site and monitor their mobility which helps to detect any hazard might occur.

An analytical study of previously published literature related to IOT. They resulted in identifying the challenges of implementing IOT, which are described in detail in Table 2.4; it illustrates the challenges identified through the study of literature, and the descriptions were developed based on these references. These challenges are from different industries worldwide and will be numerically evaluated for the case of Malaysian construction industry.

Table 2.4: Research Finding of Implementing IoT in Construction Project.

Challenges of implementing IOT in construction projects	**Factors**	**Reference**
Lack of robustness in Connectivity	It refers to the inability of existing systems to cope with errors while functioning.	(Stankovic, 2014)
Interoperability issue	Described as the incompatibility between IOT systems and devices and the difficulty to communicate and share services. It is also described as the challenge to adopt new systems into the application	(Noura et al., 2019)
Lack of documented standards	Refers to the shortage of unified standards which shapes the method of IOT application	(Al-Qaseemi et al., 2017)
Naming and identity management issues	Naming refers to the scheme of identification of computer	(Zhu & Badr, 2018)

Challenges of implementing IOT in construction projects	Factors	Reference
	across networks and resources, whereas identity management refers to the service provider that identifies the resources or users in a specific domain	
Lack of safety and security	It is the difficulty of safeguarding connected devices, information, and entities of IOT components and layers from external threat and attacks because of the connectivity to the internet. Hence, IOT is vulnerable to constant attacks if not protected	(Babar et al., 2010), (Lee & Lee, 2015), (L. Da Xu et al., 2014), (Kumar et al., 2016)
Lack of data confidentiality and encryption	Described as the susceptibility of attacking the privacy of data and lack of efficient encryption methods	(Matharu et al., 2014) (Mahmud et al., 2018) (Chahid et al., 2017)
Big data issue	Big data refers to the massive volume of data, which is complex and difficult to understand. Hence, in IOT, it is difficult	(Matharu et al., 2014)

Challenges of implementing IOT in construction projects	**Factors**	**Reference**
	to extract the relevant data required for certain function	
Improper introduction of IOT	Refers to the improper selection of methods used to apply IOT in the industry	(Mahmud et al., 2018)
Inaccuracy of data	The data are extracted from big data, which causes inaccuracy of data selection to execute a certain function	(Matharu et al., 2014)
The negative impact on society	IOT has a negative impact on the society, whereby it prioritizes things over social aspects. Furthermore, IOT caused seismic transformation on all the societal norms such as the way we communicate, work, deal and use the information	(Gamil et al., 2020) (Riggins & Wamba, 2015)
The requirement of extra budget to acquire IOT technologies	Companies are required to have the extra fund for acquiring technology and training for their employees	(Matharu et al., 2014)
The complexity of use/ technology is not user friendly	The IOT deals with big data, which makes the process more complex to execute	(Al-Qaseemi et al., 2017)

Challenges of implementing IOT in construction projects	**Factors**	**Reference**
Poor network connectivity	Refers to the level of connectivity in the targeted area where, in most cases, the availability of network coverage in construction sites remains a challenge	(Mahmud et al., 2018)
Information privacy issues	Described as the lack of information security because all things are connected to the internet, which makes them vulnerable to external attacks	(Matharu et al., 2014)
Lack of training centers	Refers to the shortage of training centers specialized in IOT tuition	(Tang et al., 2019)
Lack of IOT technology	Refers to the unavailability of network and technology in the construction site	(Tang et al., 2019)
Lack of IOT knowledge	Refers to the lack of educational resources to embark IOT knowledge	(Mahmud et al., 2018)
Poor collaboration among construction parties	The poor collaboration among the project parties can be a challenge to implement IOT because it requires all parties to work together	(Ghimire et al., 2017) (Tang et al., 2019)

2.6 Augmented Reality

Augmented Reality (AR) is a technology that enables the integration of real-time images and virtual information using a mobile interface (Zhou et al., 2008). This technology has found widespread application in industries such as entertainment, retail, travel, advertising, and social communication (Wang et al., 2013). The growing accessibility and affordability of AR technology have made its application in the construction industry more viable. Simultaneously, the potential of these tools to enhance efficiency and productivity has garnered significant interest from the architecture, engineering, construction, and facility management (AEC/FM) sector (Golparvar-Fard et al., 2011). In recent AR applications, tracking configurations can be categorized into two types: "marker-based" and "marker-less." Marker-based tracking relies on the detection of markers that can be reliably identified by mobile cameras. These markers are designed to facilitate quick alignment for efficient tracking. On the other hand, marker-less tracking configurations enable tracking of various targets without the need for markers. This type of tracking can utilize technologies such as GPS, orientation, face/image detection, and 3D maps. For the purpose of this research, the ID markers tracking configuration is adopted due to its suitability for both outdoor and indoor environments. ID markers are 2D markers with a black border that can be easily and reliably detected in straightforward applications.

Table 2.5 Augmented Reality (AR) Tools

Product Name	Manufacturer	Supplier Web Link
Layar	Layar	www.layar.com/
Hyperspaces	AR-media	www.armedia.it/
Wikitude SDK	Wikitude	www.wikitude.com/
D'Fusion Studio	Total immersion	www.t-immersion.com/

Product Name	Manufacturer	Supplier Web Link
ALVAR	VTT Technical Research Cenre of Finland	http://virtual.vtt.fi/virtual/proj2/multimedia/index.html
maxReality	Vuzix	www.vuzix.eu/
ARToolKit	DAQRI ARTruth CO. Ltd	http://artoolkit.org/
BlippAR	Blippar Group	https://www.blippar.com/

2.7 Safety at Work

Ensuring a safe and healthy environment for workers is the main collective concern of construction companies (Jalaei & Jrade, 2014). It involves both humanitarian and economic considerations. In the literature, various applications involving safety and health aspects were found. Some of these are presented in the following.

Construction may take place in hot weather, where a combination of high temperature and high moisture can pose a risk to the workers' health. An application has been built to warn about extreme work conditions (Speed et al., 2015). It uses sensor data including moisture, temperature, the workers' on-site location and their heart rates. A decision algorithm based on a neural network also considers the exposure time and basic health data of individual workers.

Automatic detection of hazardous areas on construction sites may prevent many injuries. A new application has been built (Teizer & Cheng, 2015) to compare optimal workers' paths across construction sites (the shortest possible footprints obtained from a BIM model) with actual tracking of workers' paths, with a real-time positioning system. Differences in these two paths reveal obstacles and potentially dangerous areas on the site. Consequently, the site security plan is continuously updated and does not solely depend on the security engineer.

One way to improve security at construction sites is to increase collective knowledge, which can be achieved by establishing a social network dedicated to the exchange of data on work-related accidents (Van-Tien Dao et al., 2014). The application archives data about falls from height and classifies and analyses the data statistically. It can quickly and accurately

identify weak points in protecting the life and health of workers at construction sites. The integration of smart construction environments with the world wide web is therefore a necessity, which contributes to greater safety.

Using a similar approach to the smart construction vibrator application, a new application has been developed to determine the position of construction elements through ultra-wideband radio waves (Hwang & Yeo, 2011). In this approach, sensors are positioned on the functional parts of the cranes, and the information is used to prevent collisions.

2.8 Green Element Implementation

By applying this software at the site, the user would have a great benefit and this application also could implement sustainability along with it. Some of the benefits in this application are reduce the quantity of paper usage which is sustainable for environment, it also could reduce the time and cost consume for completing the inspection work and lastly it is easy to handle and work become easier to manage in term of increase the productivity of users on construction project.

2.8.1 Sustainable System

The implementation of this system will significantly reduce the reliance on paper usage by the users. With all the necessary information and details about materials stored within the application, the need for paper-based documentation will be greatly diminished. This shift towards digital processes and reduced paper usage not only contributes to environmental sustainability but also promotes the growth and preservation of trees.

By minimizing paper consumption, the application actively supports efforts to conserve natural resources and reduce deforestation. The decreased demand for paper contributes to the preservation of forests, ensuring their long-term sustainability and protecting the biodiversity they harbor. Moreover, by reducing the amount of paper waste generated, the application aids in maintaining a healthier environment and promotes improved air quality.

In summary, the utilization of this system reduces paper usage and promotes environmental well-being by minimizing deforestation and improving air quality. By embracing digital processes and reducing reliance on paper-based documentation, the application plays a significant role in supporting a more sustainable and environmentally friendly approach to construction and inspection processes.

2.8.2 Time and Cost Management

Another significant advantage of using this application is its ability to enhance time management for on-site inspection work. By utilizing the application, users can optimize the efficiency of their reinforcement bar inspections on beam, reducing the time required for these tasks. The user-friendly nature of the application ensures that the inspection process is streamlined and straightforward, allowing for quicker and more efficient completion of tasks.

Furthermore, the portability of the application enables users to carry it anywhere without the fear of misplacing or losing important documentation. This convenience and mobility facilitate easy access to information and ensure that the application is readily available whenever needed, further contributing to time savings during on-site inspections.

Additionally, by reducing reliance on paper-based processes, the application helps in minimizing costs associated with paper wastage. The elimination of paper usage not only leads to cost savings but also reduces the environmental impact caused by paper production and disposal.

The researcher believes that the implementation of this system has the potential to significantly reduce both time and cost wastage. The efficient and streamlined nature of the application, combined with the elimination of paper-based processes, supports improved time management and cost-effectiveness in the inspection work.

In summary, this application offers time management benefits by optimizing the efficiency of on-site inspections. Its portability ensures accessibility and reduces the risk of misplacement. Furthermore, the elimination of paper usage not only saves costs but also contributes to a more sustainable and environmentally friendly approach. Overall, the system

has the potential to reduce time and cost wastage, benefiting users and enhancing the efficiency of inspection work.

2.8.3 Improve Productivity

Another key benefit of using this system is its ability to enhance work efficiency. By utilizing the application, the inspection process becomes more-streamlined and prompt, eliminating delays in on-site inspections. This efficiency improvement leads to faster completion of tasks, ensuring that projects progress smoothly and meet designated timelines.

Furthermore, the application's versatility allows it to be utilized not only by internal staff but also by clients and consultants. This inclusivity in usage promotes effective collaboration and communication among all stakeholders involved in the project. It enables better organization of work processes and ensures that everyone is aligned and working towards common goals.

The ease of use and accessibility provided by the system contribute to improved work performance and productivity. Staff and users will find it easier to carry out their tasks, resulting in increased efficiency and output. The systematic nature of the application also ensures that work processes follow a structured and organized approach, minimizing errors and enhancing overall work quality.

In summary, the implementation of this system brings about increased work efficiency through prompt inspections and minimized delays. The application's usage by clients and consultants promotes better organization and collaboration. The ease of use and accessibility positively impact productivity, while the systematic approach ensures a streamlined work process. These benefits collectively contribute to improved efficiency, productivity, and overall work performance.

2.9 Sustainable Technology

Sustainable development was coined as a key concept governing development in the “Our common future,” which is also known as the Brundtland report (WCED, 1987). Sustainable development was defined here as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, and subdivides it down into three aspects; environmental sustainability, social sustainability, and economic sustainability.

Over the years the three aspects of sustainability have also evolved from environmental sustainability to resource management, social sustainability to design for human, and economic sustainability to life-cycle design with relation to building construction industry (Sev, 2008). By utilizing the Augmented Reality Application, the construction industry can improve the overall quality of work in inspection processes. This technology enables a more accurate and efficient examination of construction elements, ensuring that inspections are carried out with precision and attention to detail. The application's capabilities in providing real-time information and visual aids enhance the accuracy and effectiveness of inspections, contributing to improved work quality and adherence to industry standards.

Furthermore, the adoption of the Augmented Reality Application aligns with sustainability strategies within the construction and property sectors. By utilizing technology-driven solutions, such as augmented reality, the industry can reduce resource consumption, minimize waste, and enhance overall environmental performance. This application offers a more sustainable and efficient approach to inspection work, contributing to the industry's sustainability goals.

In summary, the implementation of the Augmented Reality Application on the Sunway Belfield site aligns with sustainability objectives in the construction and property industries. The application's use improves work quality by facilitating accurate and detailed inspections. Moreover, by leveraging technology, the industry can enhance sustainability practices and reduce environmental impact.

2.10 Conclusion

The building sector is now embracing technology, and construction companies that adopt and leverage technology experience increased productivity, improved collaboration, and timely project completion within budget. These factors ultimately lead to higher gross margins. Conversely, businesses that fail to invest in cutting-edge technologies and solutions are at risk of lagging behind their competitors. Construction firms that do not embrace new technologies are likely to face challenges and struggle to survive.

Furthermore, the digital revolution in the construction industry presents exciting opportunities, including gaining a competitive edge, enhancing working conditions, and reducing the industry's carbon footprint. The researcher predicts that in the future, the adoption of modernization technology will become a requirement for all corporate businesses, and the construction industry will reach a point where it is no longer an option but a necessity.

The adoption of technology in the building sector is proving to be crucial. Construction firms that actively develop and utilize technology are experiencing several benefits, such as increased production, improved collaboration among teams, and the ability to complete projects on time and within budget. These positive outcomes ultimately lead to higher gross margins for the firms.

On the other hand, businesses that neglect to invest in innovative technologies and solutions are falling behind their counterparts. The construction industry is evolving rapidly, and firms that fail to adapt to these changes are at risk of collapse.

Moreover, the digital revolution in the construction industry opens up numerous exciting prospects. Embracing technology not only helps companies gain a competitive edge but also contributes to improving working conditions for employees and reducing the industry's overall carbon footprint. It is predicted that in the future, the adoption of modernization technologies will become a mandatory requirement for all corporate businesses. The construction industry will reach a point where technological advancements are no longer optional, but rather an essential component for success.

CHAPTER 3

METHODOLOGY

3.1. Introduction

A design process is the process of transforming a brief requirement into a finished product or design solution. The design process involves a high level of creativity, but it is controlled and directed by the process so that it is channeled towards producing a viable, practical solution to the design problem, meeting or exceeding the stated aims of the brief. While creativity is important in design, design is an activity that serves both economic and creative goals. The design process aids in ensuring that a design meets all these criteria. The process is critical for generating many potential solutions and employs a variety of techniques or mechanisms that encourage participants to think outside the box in the pursuit of a creative or innovative solution (Dong et al., 2021).

Many people and organizations have discovered the power of Design Thinking in the creation of innovations in recent years. This method combines user perspectives,

technological feasibility, and business perspectives to create innovative solutions that go above and beyond what is expected. Design Thinking has the potential to change the way we work by altering how we think, approach problems, and develop products and services (Elsbach & Stigliani, 2018).

3.2 Design Research

A researcher's research design is the framework for the methods and techniques he or she will use to conduct research. The design enables researchers to focus on research methods that are appropriate for the subject matter and to set up researcher studies for success. This method is critical for planning any observation. Implementation steps should be monitored to identify potential problems. If there is a critical issue that is a major cause of failure in the implementation of the work, changes must be made. Following that, control measures must be implemented in order to maintain a constant flow.

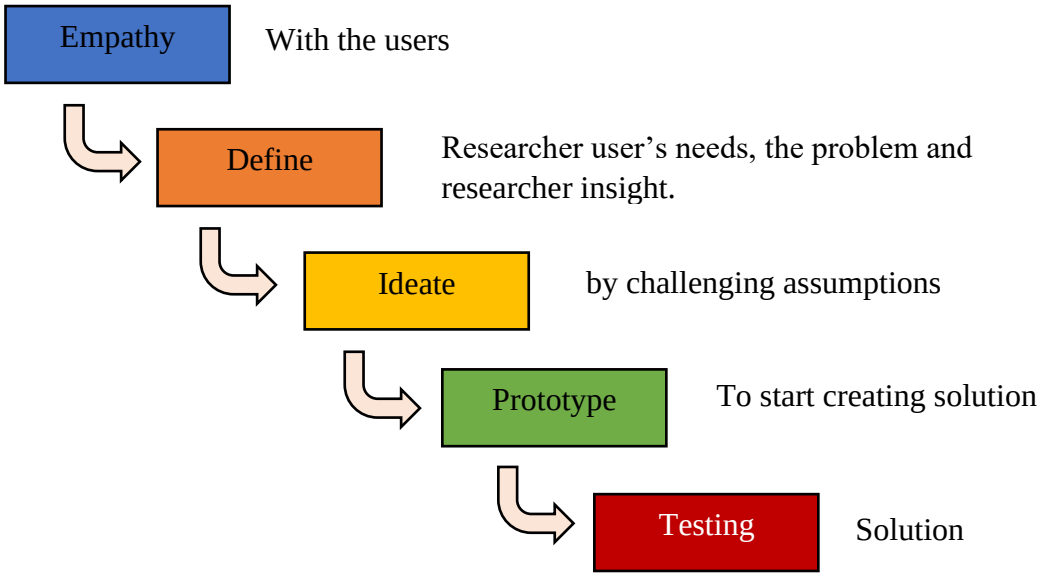
Table 3.1 Research Design

Objectives	Method	Material
To identify application of beam reinforcement bar information and details that can allows users to access information on the details of reinforcement bar.	Identify Survey Interview	i. Background Company ii. 2D Plan of the Building iii. Details of Reinforcement Bar on slab iv. Autodesk AutoCad
To develop a rebar inspection of beam application using the Augmented Reality Application.	Develop	i. BlippAR
To validate the effectiveness of Augmented Reality Application for inspection work construction.	Survey	i. Survey ii. Questionnaire

Furthermore, in order to create a solution, design thinking must be applied in order to achieve the desired outcome. Design Thinking is an iterative process in which researchers

seek to understand the user, challenge assumptions, and redefine problems in order to identify alternative strategies and solutions that may not be immediately obvious based on our initial level of understanding. Simultaneously, Design Thinking offers a solution-based approach to problem solving. It is a way of thinking and working, as well as a set of practical methods.

Design Thinking is based on a strong desire to understand the people for whom the researcher is creating products or services. It enables the researcher to observe and develop empathy for the target user. Design Thinking assists researchers in the process of questioning: questioning the problem, the assumptions, and the implications. Design Thinking is extremely useful in tackling ill-defined or unknown problems by re-framing the problem in human-centric ways, brainstorming many ideas, and taking a hands-on approach to prototyping and testing. Sketching, prototyping, testing, and trying out concepts and ideas are all part of Design Thinking. Design Thinking has five stages, which are as follows:



3.3 Development of Research

This study's research framework is design thinking. Figure 3.1 depicts a research framework in which the flow of the study considered for this project is depicted. Research development is a set of strategic, proactive, catalytic, and capacity-building activities that

assist individual faculty members, teams of researchers, and central research administrations in attracting extramural research funding, building relationships, and developing and implementing strategies to improve institutional competitiveness. In this section, the researcher thoroughly explained how the application worked from the beginning to the end of the product. Before beginning the application, it was necessary to create a flowchart design to help with understanding.

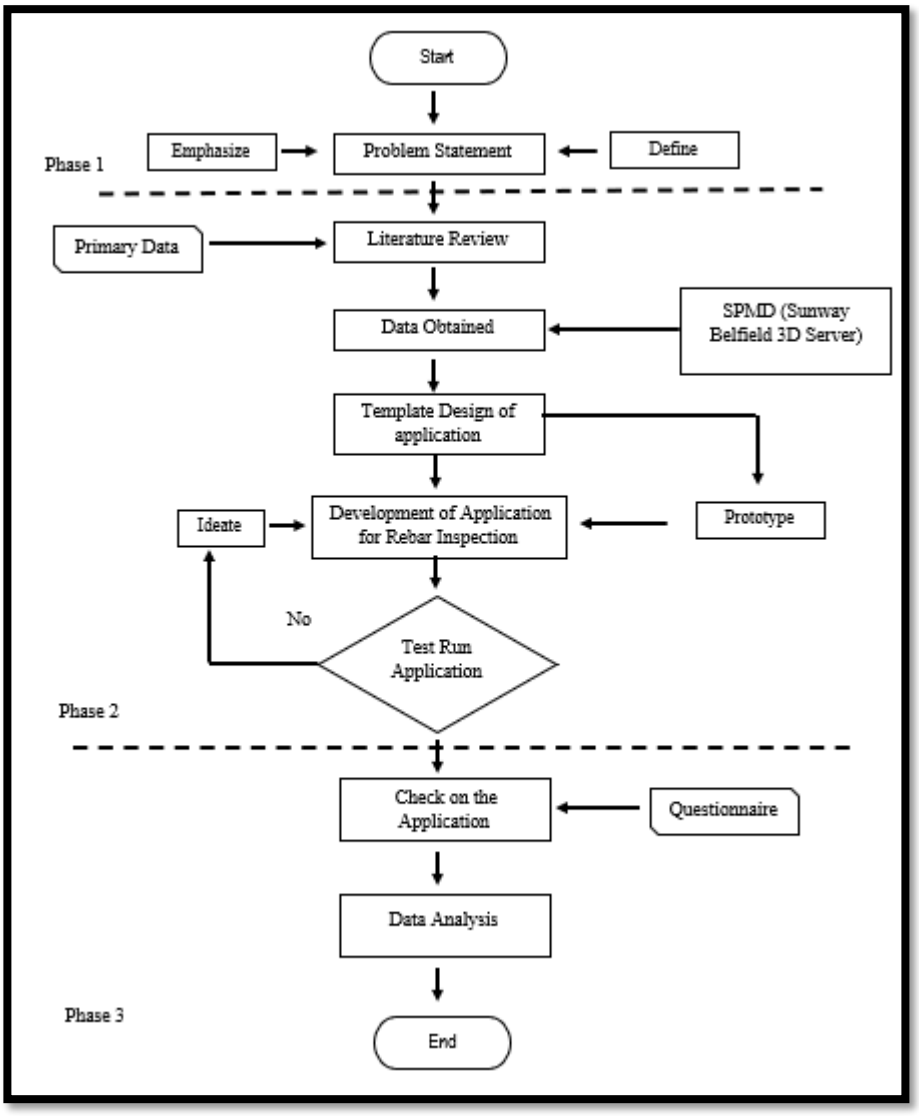


Figure 3.1 Flow of research framework

This study's methodology is divided into several phases, which will be explained in detail. In addition, other methods are used to conduct interviews, read the results of literature review research studies, create a questionnaire, and preview the project's progress. Throughout the project completion process, three phases of methodology will be involved.

For example:

Phase 1 – Discovery of problems and review of literature

Phase 2 – Data Collection Method

Phase 3 – System production (Data Testing, Analysis, and Interpretation of Data) and Recommendation and Conclusion.

3.3.1 Phase 1 (Problem Discovery and Literature Review)

The most important aspect of this phase is planning the design and analysis of the project that will be created. This phase focuses on gathering the information needed for project development as well as discussions with the supervisor and mentor. It took at least two weeks to complete this phase.

3.3.2 Phase 2 (Method of Data Collection)

The main goal of this phase is to analyze and compare the previous and most recent applications on the market. The analysis included both the fact-finding technique, the questionnaire, and the interview method. The information gathered will be used to create the product.

i. Primary Source

To obtain difficult facts, the interview and observation were conducted using a questionnaire. This interview process is critical to obtain certainty and detailed information about the analyzed factors based on survey feedback. This information is gathered through direct contact with those involved in construction projects involving contractors and professionals.

ii. Secondary Source

This data emphasizes the importance of this study. Furthermore, these data are required to obtain additional information about this study. Additional information obtained as project-related material. Gather the materials for future reference.

3.3.3 Phase 3 (Method of Data Analysis)

Some activities that will be implemented immediately following the completion of the entire innovate in the system will be tested to ensure that the software execution is error-free. The project's catalogue materials will also be collected.

3.4 System Design and Development

The process of designing the components, modules, interfaces, and data for a system in order to meet specific criteria is known as system design. The process of creating or altering systems, as well as the procedures, techniques, models, and methodologies required to do so, is referred to as system development (Holder & Wang, 2021). The researcher revealed all the critical breakdowns on how the system was designed and developed in this section. During the application's initial launch, this section was taught one by one, including how to sign up and how it worked.

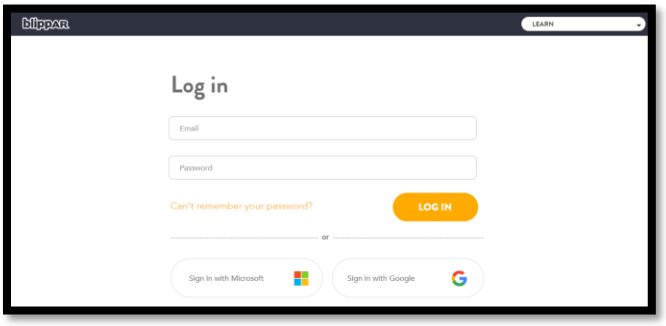
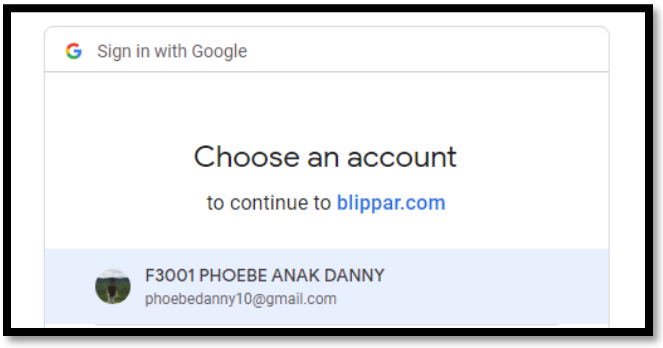
3.4.1 System Design

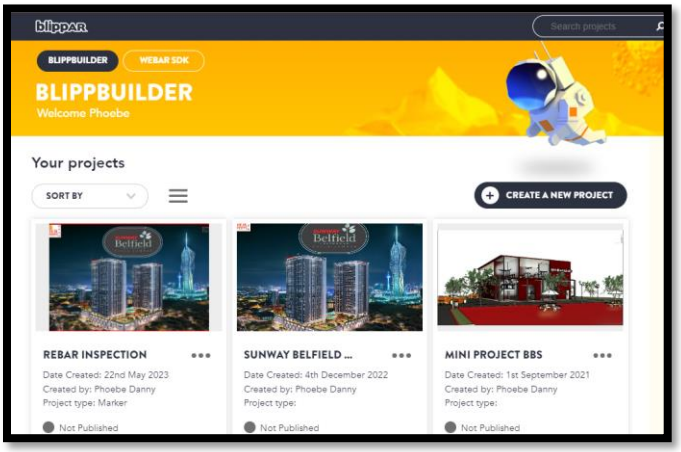
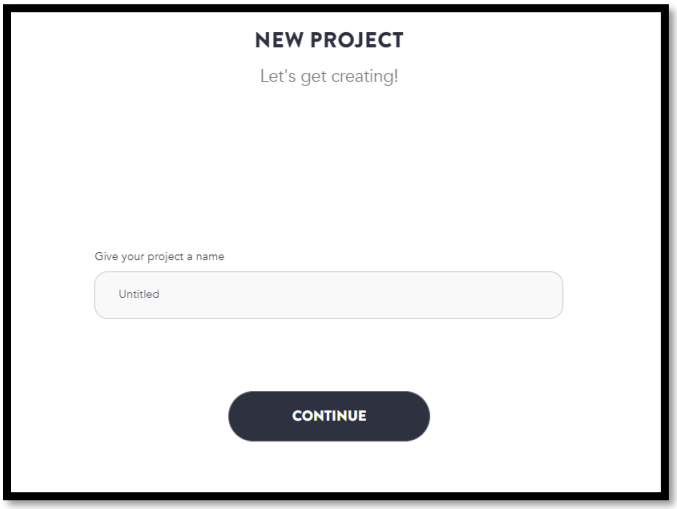
Blippar Blippbuilder is a software development kit that enables the creation and execution of augmented reality experiences on mobile web browsers. Using WebAR BlippBuilder and A-Frame or PlayCanvas, it is simple to develop AR experiences that interact realistically with objects and environments. WebAR Blippbuilder is also a class library that interacts with several application programming interfaces (APIs) to produce a distinct set of augmented

reality and plane detection capabilities that can be implemented into third-party apps. It also employs device motion sensors to track and stabilize an item on any surface.

Developers may use the WebAR Blippbuilder to build and publish augmented reality content in their online environment. While augmented reality allows virtual items to be rendered in the real world, WebAR Blippbuilder provides for exact positioning and tracking of such elements in order to create an immersive online experience. It is compatible with online content standards such as HTML and WebGL that offer 2D and 3D graphics. It may use numerous JavaScript-based library and framework capabilities in AR apps (Chrome, Safari, etc.) to develop AR on mobile web browsers that comply to web standards.

To use the WebAR Blippbuilder will need a License which is log in to personal Google Account. This will always be FREE to get started, additionally during our Beta period you will also be able to build Unlimited WebAR experiences within your infrastructure viewed Unlimited* times. These AR experiences work on every mobile device browser.

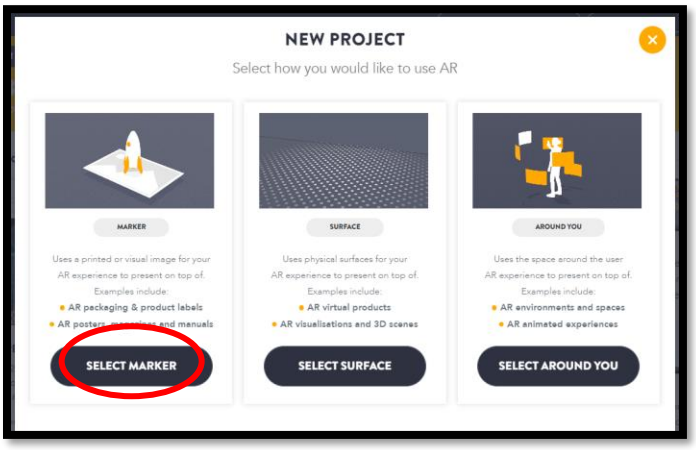
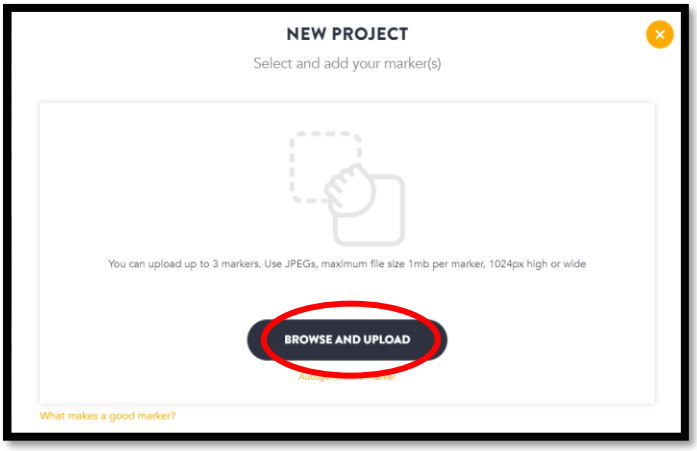
	Sign Up or Login
	If already sign up, choose Google Account to Login.

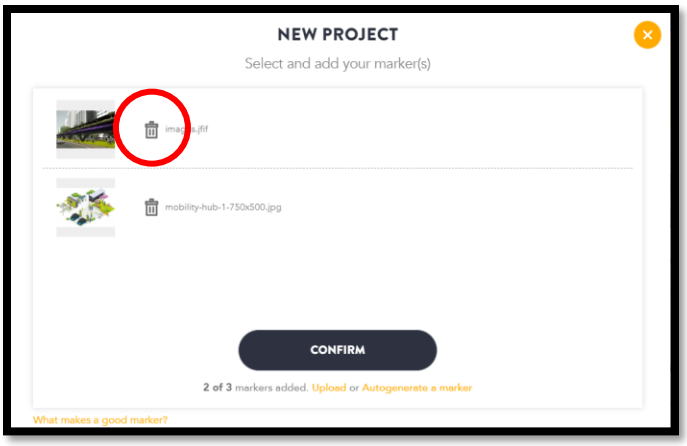
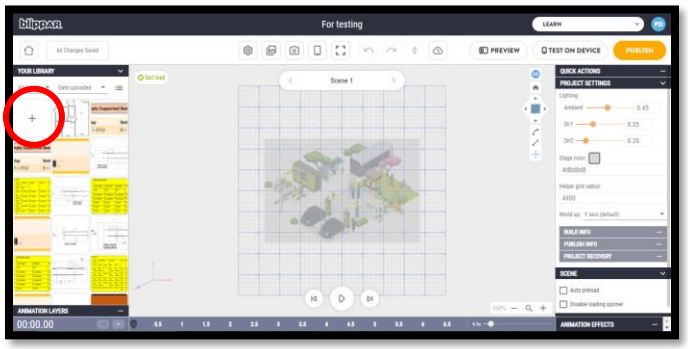
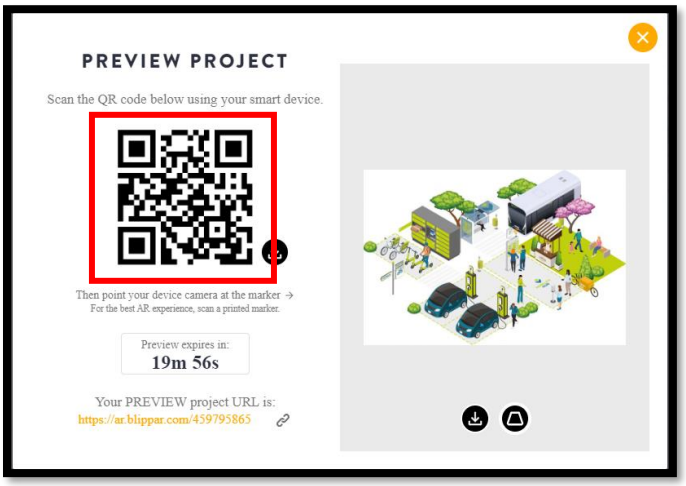
	Once login, you can click on 'Create a New Project' to create your augmented reality content.
	Give your project a name and enter the domain where you will host the AR experience. WebAR Blippbuilder will always be free to get started with, and it is free to publish with unlimited views.

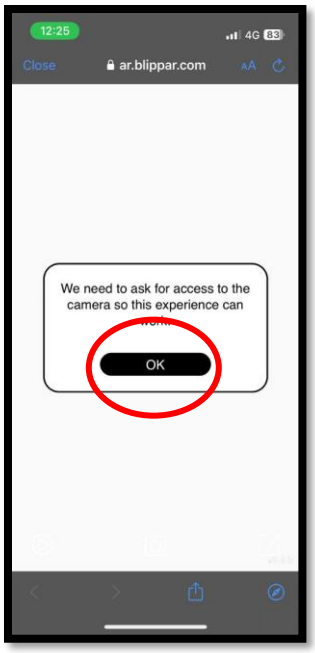
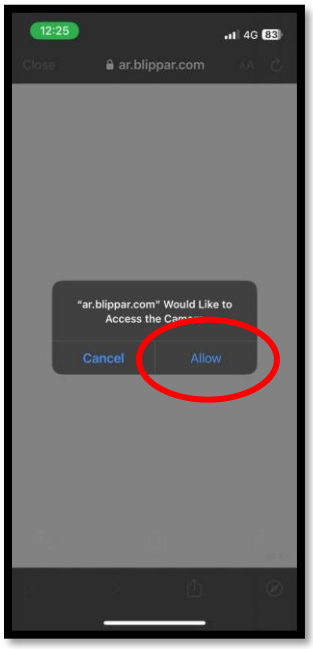
3.4.2 System Development

The rebar inspection application was created step by step to ensure the application's success. This application was for users especially Engineers, Inspector of Work (IoW) and Site Supervisor to use during beam reinforcement bar inspection work. The steps for using Rebar Inspection work are shown in the table below.

Table 3.2 System Development

Prototype	Explanation
	Login to BlippAR. Click 'Select Marker' tab as shown in the image on the left.
	Click 'Browse and Upload' markers Choose the desired marker you wish to upload. It can alternatively 'Drag and Drop' your marker as shown in the image above. Up to 3 markers images can be tracked one at a time.

Prototype	Explanation
	Click 'Browse and upload' markers or alternatively 'drag and drop' desired marker in the section as shown in image. The uploaded markers can be seen in the 'Manage Marker' section. Click on the bin icon to delete an uploaded marker as shown in the image below. After that, click Confirm.
	Upload all information of the Sequence for loading bay.
	To preview your project, scan the QR Code. Scan your photo by clicking on the icon. Success to access blippAR Able to access all information that had be upload on BlippAR

Prototype	Explanation
	After Scan the QR Code on your Smartphone, it will directly access to BlippAR application. Click 'Ok' on the application to continue review the content.
	Click 'Allow' to access camera on that BlippAR application.

Prototype	Explanation
	Click 'Allow' on the screen to continue preview the content in the application.

3.5 Architecture Diagram

The Architecture Design of this application is created by using Excel.

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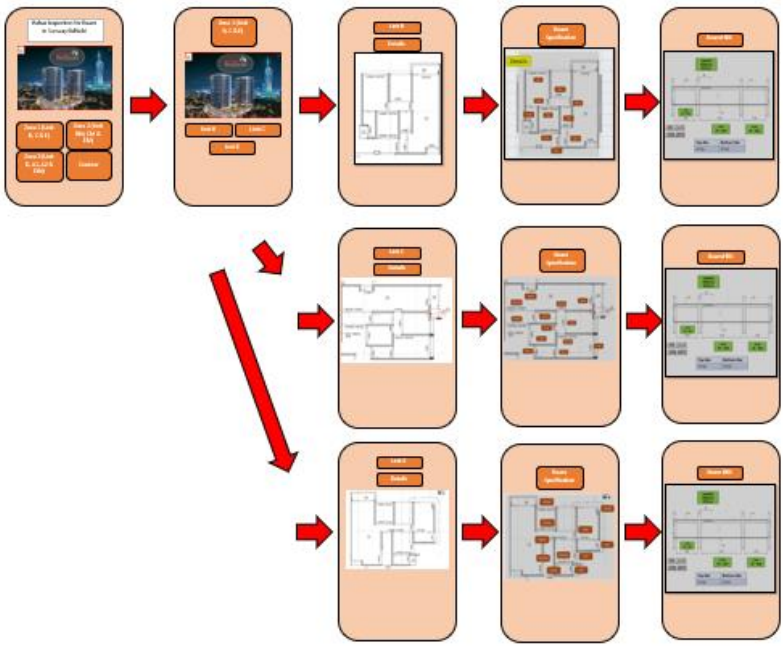


Figure 3.2 Architecture Diagram of the Application

3.6 Testing of Product

Rebar Inspection using Augmented Reality Application has been invented to enable users to be tested. The Rebar Inspection using Augmented Reality Application was specifically designed to undergo a trial period to assess its effectiveness among company staff and other relevant individuals who can utilize the product for testing purposes. This trial period allows the application to be employed in real-world scenarios, enabling users to provide valuable feedback and insights regarding its efficiency.

In order to assess the effectiveness of the application, participants were invited to participate in an online survey that was meticulously crafted to collect data on multiple facets of the application's performance and usability. The primary objective of the survey was to gauge how well the application addresses the company's problem and whether it provides satisfactory outcomes in comparison to existing methods. By utilizing both pre and post methods, a thorough evaluation of the innovation was conducted, ensuring precise and reliable results.

The survey primarily centered around key aspects such as the application's user-friendliness, usefulness, attitudes towards adopting technology, and intentions to use the Rebar Inspection using Augmented Reality Application. These variables were derived from the reputable Technology Acceptance Model (TAM) questionnaire, a widely recognized tool for evaluating users' acceptance and adoption of new technologies. By collecting feedback from participants, the company can acquire valuable insights into the application's strengths, weaknesses, and areas that require improvement. This feedback can subsequently be employed to refine and enhance the application, thereby increasing its effectiveness in addressing the specific problem it aims to solve.

In order to ensure that the Rebar Inspection using Augmented Reality Application meets the expectations and requirements of users, conducting a trial period and gathering feedback through an online survey is of utmost importance. This approach allows for the identification of any potential issues or challenges that need to be addressed before the application is fully implemented.

In conclusion, the trial period and subsequent online survey are vital steps in evaluating the effectiveness of the Rebar Inspection using Augmented Reality Application. By involving company staffs and other relevant individuals, their feedback and experiences provide valuable insights into the application's usability and efficiency. This feedback-driven approach ensures that the final product is customized to address the specific needs of the company and effectively resolves the identified problem.

3.7 Data Collection and Analysis

The product was tested using online questionnaire. This product was developed using BlippAR and were tested among 13 employees from Sunway Construction SDN BHD, TYlin, IRC Builder, Primetech, IDH, Potential SDN BHD, and CSBS SDN BHD. They are consisting of engineer, site supervisor, inspector of work. The questionnaire was adapted from Technology Acceptance Model by Davis (1988). Technology Acceptance Model (TAM; Davis, 1989) has been one of the most influential models of technology acceptance, with two primary factors influencing an individual's intention to use new technology: perceived ease of use and perceived usefulness (Granić & Marangunić, 2019). The sample size was determined using Krejcie and Morgan Table (1970) whereby for population of 13 respondents, 13 samples were adequate. TAM seeks to explain and predict individuals' acceptance and adoption of new technologies based on their perceived usefulness and perceived ease of use. The model has been widely used in the field of information systems and technology research to understand users' attitudes and behaviors towards technology. The key components of the Technology Acceptance Model (TAM) are as follows:

i. Perceived Usefulness (PU): This component refers to the user's perception of how much a particular technology or application can enhance their job performance or productivity. It assesses the extent to which users believe that using the technology will be advantageous to them.
ii. Perceived Ease of Use (PE): This component evaluates the user's perception of how easy it is to learn and use the technology. It measures the user's belief regarding the simplicity of operating the technology and the ease with which they can become proficient in using it.

iii. Attitudes Towards Technology Adoption (ATU): This component focuses on the user's general attitude towards adopting new technologies. It assesses their openness and willingness to try new technologies and their belief in the potential benefits that can be derived from adopting them.

iv. Behavioral Intention to Use (IU): This component measures the user's intention to use the technology in the future. It assesses their willingness to use the technology on a regular basis and their intention to recommend it to others.

These components are interrelated, and they collectively contribute to the user's acceptance and adoption of a new technology. The TAM provides a framework to understand and predict user behavior towards technology by considering these key components. TAM has gained significant popularity in studying the acceptance and adoption of various technologies, ranging from software applications and e-commerce systems to mobile apps and more. Over the years, researchers have extended and modified TAM by incorporating additional factors and variables to better explain users' attitudes and behaviors towards technology. This framework proves invaluable in understanding technology acceptance, thereby aiding the design, development, and implementation of new technologies to enhance user adoption.

To determine the appropriate sample size, researchers referred to the Krejcie and Morgan Table (1970), which recommended a sample size of 15 for a population of 15 respondents. Additionally, a simulation study conducted by De Winter (2013) demonstrated that using a regular t-test with extremely small sample sizes does not pose any fundamental objections. Notably, De Winter emphasized that even a sample size as small as 2 can be used without significant issues.

The researchers opted to collect data for their study by utilizing a Google form. This method allowed them to provide the respondents with a user-friendly and convenient platform to complete the questionnaire. After the data collection phase, the researchers extracted the collected data from Microsoft Excel software for further analysis. To analyze the data, they chose to employ Paired T-test software, which was accessible through a statistical analysis online software. The selection of Paired T-test software was based on its

efficiency and user-friendly features, enabling the researchers to derive meaningful insights and actionable conclusions from the collected data.

The analysis process involved several steps, starting from extracting the data from Microsoft Excel and proceeding to perform the Paired T-test analysis using the designated software. This statistical analysis will provide a comprehensive assessment of the application's effectiveness by comparing the responses before and after the implementation of the Rebar Inspection using Augmented Reality Application. By employing this methodology, the researchers aim to gather valuable data on the usability and effectiveness of the application. The questionnaire served as an essential instrument for data collection, providing insights into the participants' perceptions and acceptance of the new technology.

3.8 Identifying Application for Beam Reinforcement Bar

The purpose of the Rebar Inspection Using Augmented Reality application is to simplify the tasks previously performed through conventional methods and provide real-time updates on a mobile device. In the past, engineers, supervisors, and consultants had to conduct inspection of beam by using traditional methods such as refer to 2D drawing on A3 size of paper. These methods were time-consuming and non-sustainable resulting in delays in processing casting or addressing any issues related to the accuracy of reinforcement bar in beam. This inefficient process lacked systematicity and was not suitable for long-term use. To address these challenges, the Rebar Inspection Using Augmented Reality application was designed as a solution, streamlining communication, and providing a systematic approach to conducting inspection in construction site.

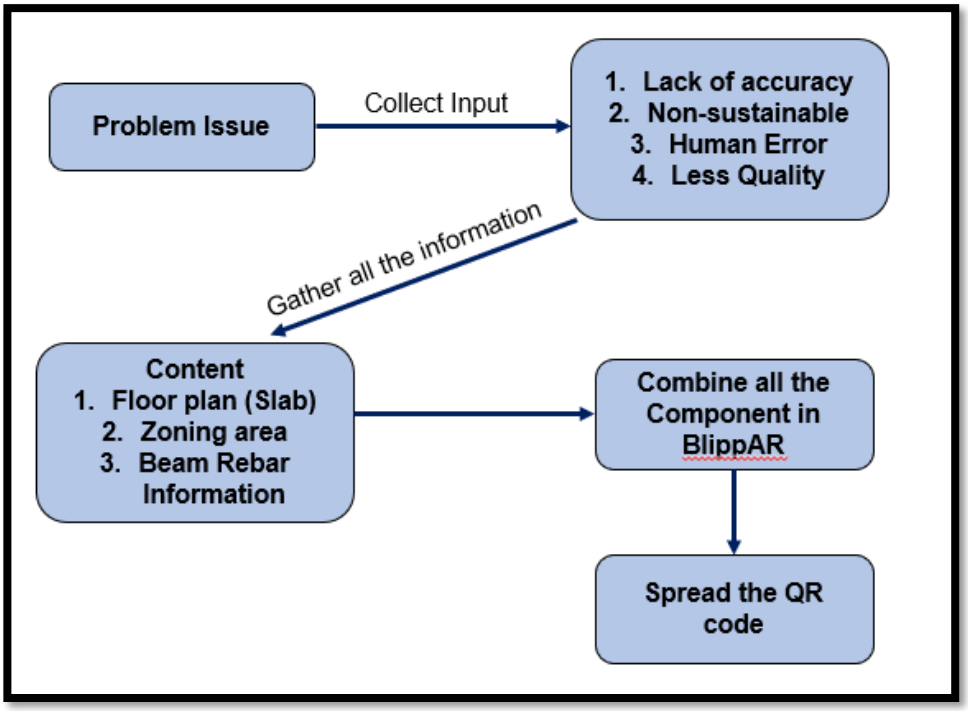


Figure 3.3: Flowchart of Design Rebar Inspection using Augmented Reality Application using BlippAR.

The Rebar Inspection Using Augmented Reality application provides engineers, site supervisor and other relevant stakeholders with convenient access to information regarding the reinforcement bar details. By utilizing this application, time can be saved, and project delays can be minimized since all tasks related to the mega column work and casting progress can be efficiently pre-planned. Furthermore, the application empowers users to ensure the accurate completion of required tasks. Real-time results can be seamlessly accessed while working on the construction site, enabling users to effectively track and monitor progress.

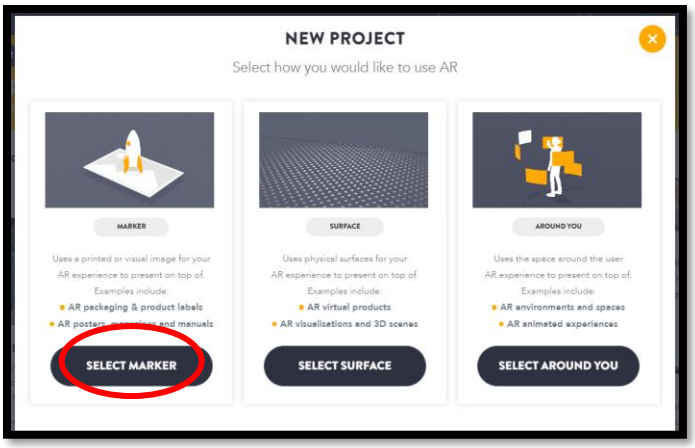
3.9 Developing Rebar Inspection Using Augmented Reality Application via BlippAR

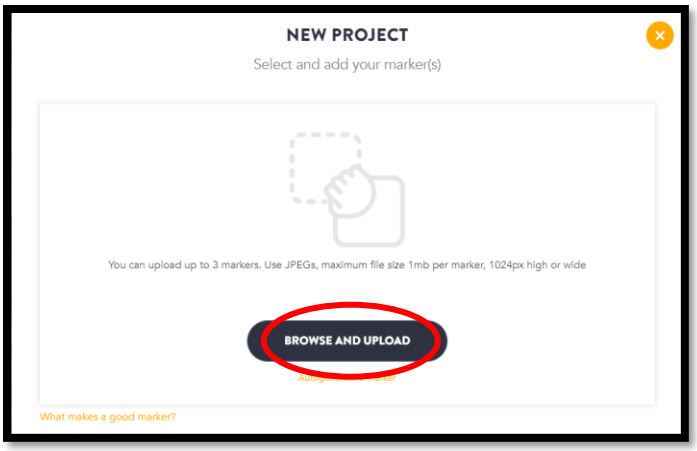
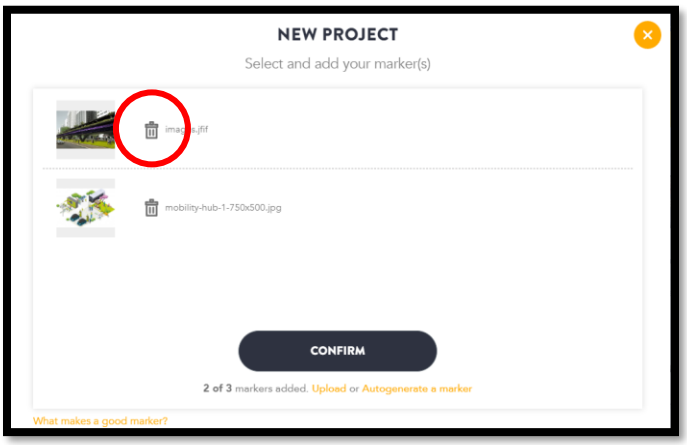
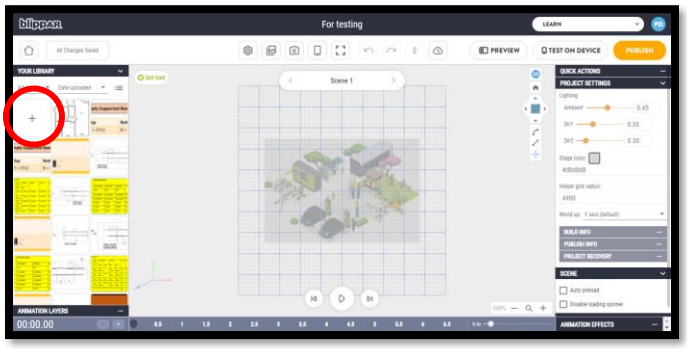
BlippAR is an Augmented Reality (AR) application that offers an immersive and interactive user experience. It allows users to overlay digital content, such as 3D models, videos, or animations, onto the real world through their mobile devices or AR-enabled smart glasses. BlippAR utilizes computer vision technology to recognize and track objects or markers in the physical environment, enabling the seamless integration of virtual elements into the user's surroundings.

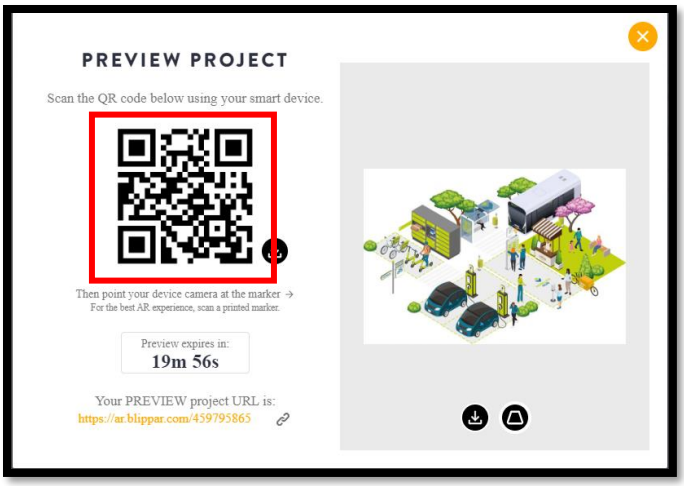
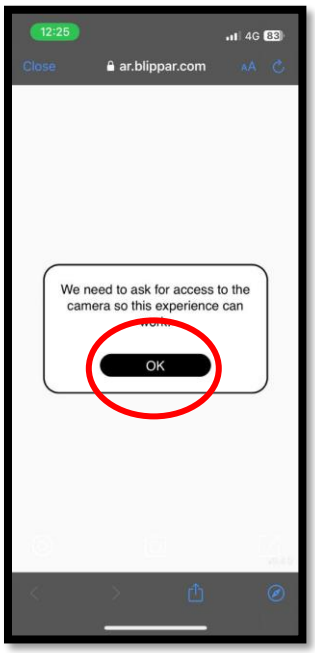
The application has various applications across industries, including marketing, advertising, education, and entertainment. It enables brands to create engaging AR campaigns and experiences, allowing consumers to interact with products and access additional information or promotional content. In the educational realm, BlippAR Buildbuilder can be utilized to enhance learning by providing interactive and visual explanations of complex concepts.

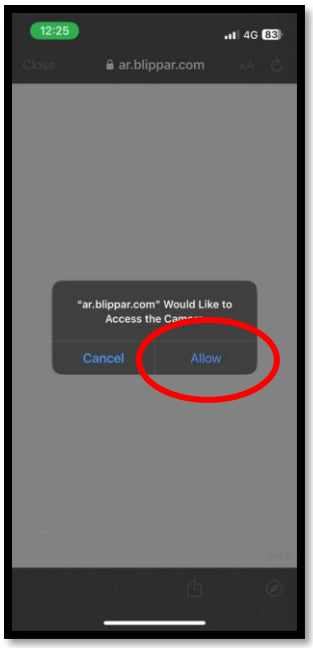
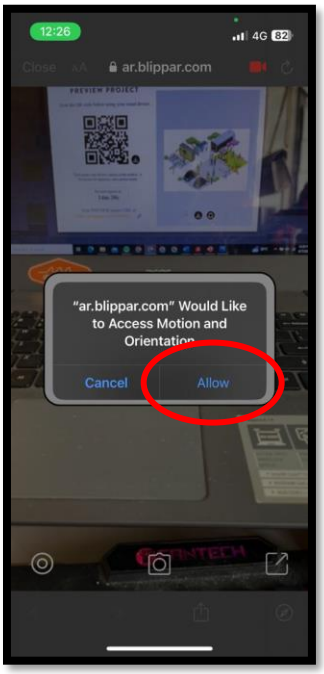
BlippAR offers a user-friendly interface and intuitive controls, making it accessible to a wide range of users. It leverages the power of AR to bridge the gap between the physical and digital worlds, opening new possibilities for immersive and interactive experiences.

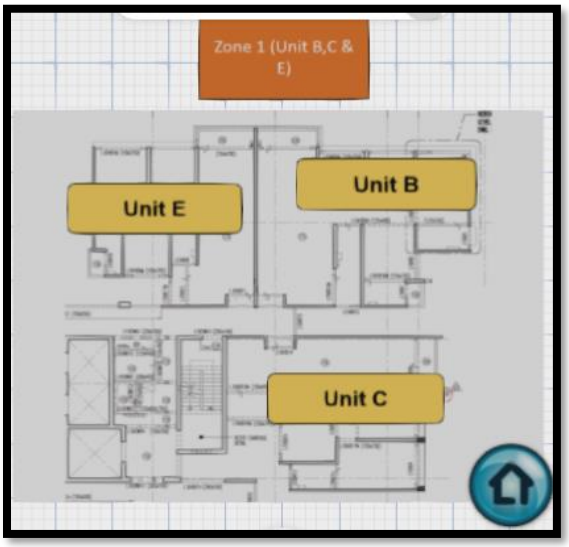
Table 3.3 Rebar Inspection Using Augmented Reality Application Design

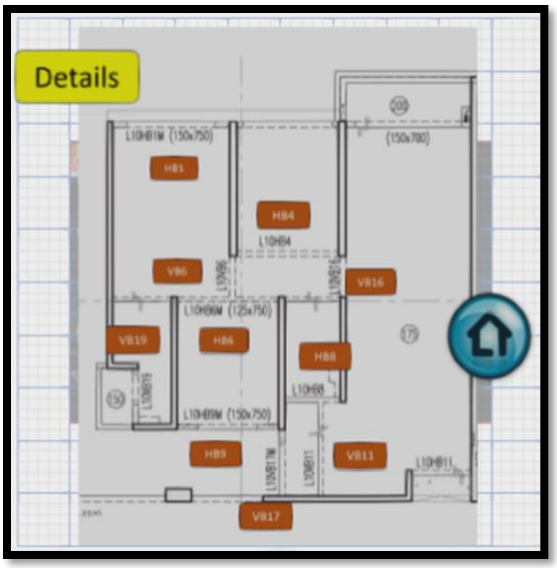
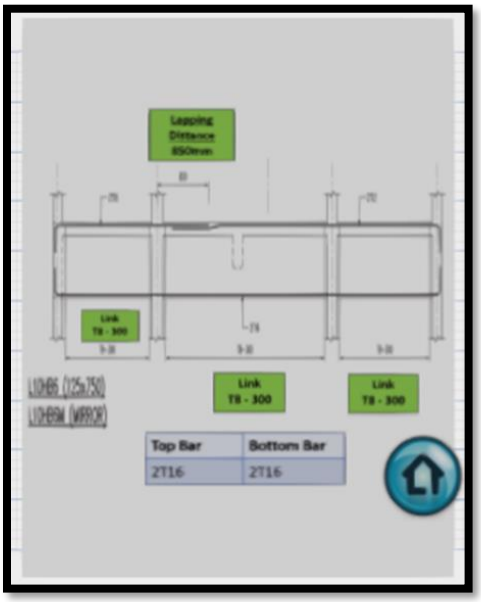
Prototype	Explanation
	Login to BlippAR. Click 'Select Marker' tab as shown in the image on the left.

Prototype	Explanation
	Click 'Browse and Upload' markers Choose the desired marker you wish to upload. It can alternatively 'Drag and Drop' your marker as shown in the image above. Up to 3 markers images can be tracked one at a time.
	Click 'Browse and upload' markers or alternatively 'drag and drop' desired marker in the section as shown in image. The uploaded markers can be seen in the 'Manage Marker' section. Click on the bin icon to delete an uploaded marker as shown in the image below. After that, click Confirm.
	Upload all information of the Sequence for loading bay.

Prototype	Explanation
	To preview your project, scan the QR Code. Scan your photo by clicking on the icon. Success to access blippAR Able to access all information that had be upload on BlippAR
	After Scan the QR Code on your Smartphone, it will directly access to BlippAR application. Click 'Ok' on the application to continue review the content.

Prototype	Explanation
	Click 'Allow' to access camera on that BlippAR application.
	Click 'Allow' on the screen to continue preview the content in the application.

Prototype	Explanation
	The first preview will show this content which has 3 zoning areas and for google form. 1. Zone 1 (Units B, E, and C) 2. Zone 2 (BM, EM, and CM Units) 3. Zone 3 (Unit D, A1, A2 and DM) 4. Google form after checking.
	Click on Zone 1 button, it will directly show this content which is showing the type of units.

Prototype	Explanation
	Click on button “Unit E” and all the beam detailing will pop up just as shown in the picture.
	Click on the beam detailing button, it will directly show all the information needed for the beam. Click “Home button” when inspection for the beam is done.

3.10 Evaluating the effectiveness of the Rebar Inspection Using Augmented Reality Application

The final product underwent testing through an online questionnaire. The product was developed using BlippAR Buildbuilder and was tested among a group of 13 employees from Sunway Construction SDN BHD, including engineers, site supervisors, construction managers, and consultant. The purpose of the testing was to identify areas for improvement in the conducting inspection for beam reinforcement bar. The surveys were conducted with the 13 respondents, and the results obtained will be presented in a comprehensive manner through tables, graphs, and figures, highlighting key information and providing a thorough analysis of the study.

The questionnaire utilized in this study consisted of four sections: Section A, Section B, Section C, and Section D. Section A gathered demographic information from the respondents. Section B focused on questions related to the effectiveness categories. Section C assessed the perceived ease of use of the technology. Lastly, Section D explored the intention to use the technology.

The questionnaire employed in this study was based on the well-known Technology Acceptance Model (TAM) proposed by Davis in 1989. TAM is widely used for understanding the acceptance of new technologies, with a particular emphasis on two key factors: perceived ease of use and perceived usefulness, which both influence an individual's intention to use a new technology. The variables measured in this study align with TAM, including perceived ease of use, perceived usefulness, attitude towards using technology, and behavioral intention to use.

The sample size for this study was determined based on the Krejcie and Morgan Table from 1970. As the population consisted of 16 respondents, a sample size of 16 was deemed adequate. Therefore, all individuals in the population were included in the study. Furthermore, a simulation study conducted by De Winter in 2013 showed that even with very small sample sizes, such as 2, there were no significant issues when using a regular t-test.

The subsequent section of the questionnaire delved into the demographic data, providing background information about the respondents. This section comprised five items, including:

i. Gender
ii. Age Group
iii. Organization
iv. Designation
v. Work Experience

i. Gender

Table shows the number of respondents who obtained in this study. The total number of respondents was about 13 persons. Table 3.4 and Figure 3.4 below show the number of respondents by gender.

Table 3.4: The number of respondents by gender

No	Gender	No respondent	Percentage (%)
1	Male	13	100%
2	Female	0	0%
Total		13	100%

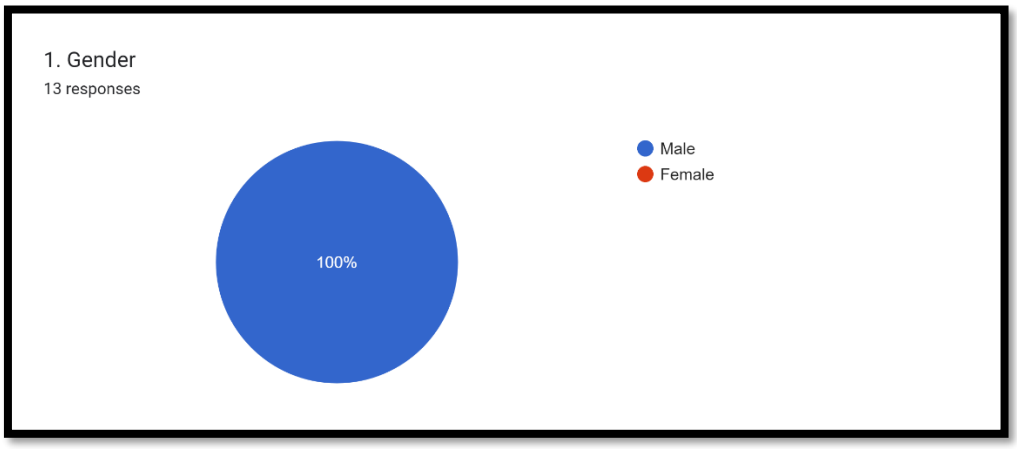


Figure 3.4 The number of respondents by gender

Out of the total respondents, 13 individuals were male, while there is no respondent from female. This translates to a percentage rate of 100% for male respondents and 0% for female respondents. The data clearly indicates that there was a higher representation of male respondents in the construction site compared to female respondents.

ii. Age Group

Table presents the age categories of the respondents who participated in this study. The researchers categorized the respondents into four age groups to ensure effective data analysis and to better understand the demographic distribution at the construction site. The corresponding percentages based on age can be observed in Table 3.5 and Figure 3.5.

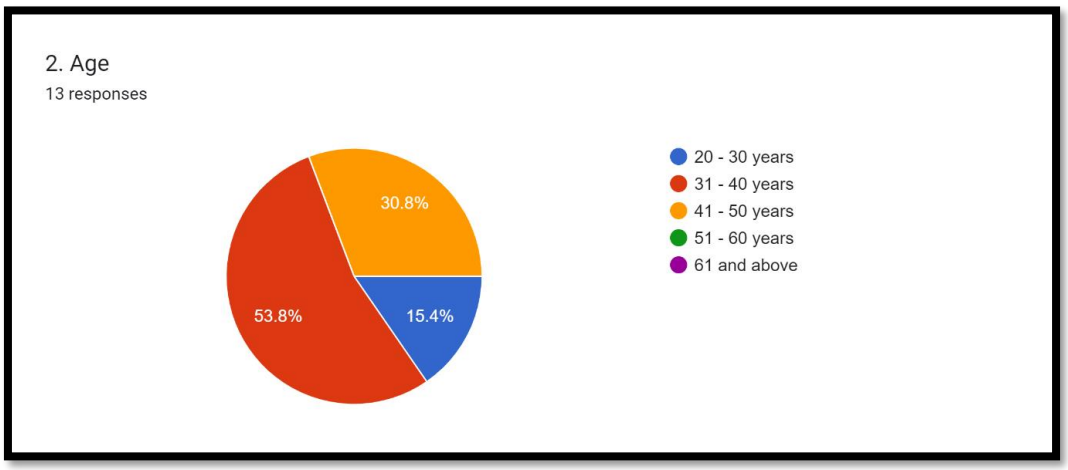


Figure 3.5 The number of respondents by age

Table 3.5 The number of respondents by age

No	Gender	No respondent	Percentage (%)
1	20 - 30	2	15.4%
2	31 – 40	7	53.8%
3	41 - 50	4	30.8%
4	51 - 60	0	0%
5	61 and above	0	0%
Total		13	100%

Through the findings, the high percentage is the range of 31-40 years representing 53.8%. The percentage of 41-50 years of age was reduce by 3 person and age group 20-30 years only with the percentage of 15.4%.

iii. Organization

Table 4.4 below show the number of respondents organization that involved in this construction. The total was 13 persons. Table 3.6 and figure 3.6 below show the number of respondents by every organization.

Table 3.6 The number of respondents by organization

No	Organization	No respondent	Percentage (%)
1	Sunway Construction	2	15.4%
2	TYlin	4	30.8%
3	IRC	2	15.4%

No	Organization	No respondent	Percentage (%)
4	CSBS SDN BHD	1	7.7%
5	Primetech	1	7.7%
6	Potential	2	15.4%
7	IDH	1	7.7%
	Total	13	100%

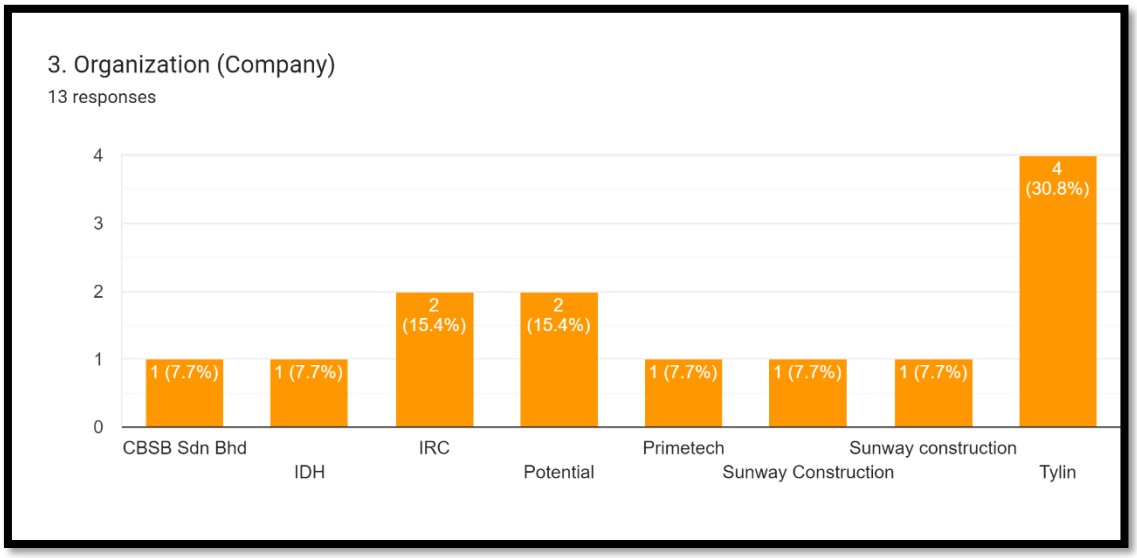


Figure 3.6 The number of respondents by organization

Based on this finding, the high percentage of respondents is TYlin that interest in this product. The range of respondents for TYlin is 30.8% followed by Sunway Construction, IRC and Potential 15.4%. This showed that 2 organizations quite interested in this product.

iv. Designation

The third item in the demographic data is the position at construction site, where there are various positions of Project Engineer, Resident Engineer, Site Supervisor, and Inspector of Work (IOW) where is responsibility and follow up the progress of Rebar Inspection Application. Figure 3.7 and Table 3.7 below appointment pie chart illustration and table.

Table 3.7 The number of respondents by designation

No	Designation	No respondent	Percentage (%)
1	Director/Manager	0	0.0%
2	Inspector of Work	5	38.5%
3	Project Engineer/Resident Engineer/Executive/Coordinator	4	30.8%
4	Site Supervisor	4	30.8%
	Total	13	100%

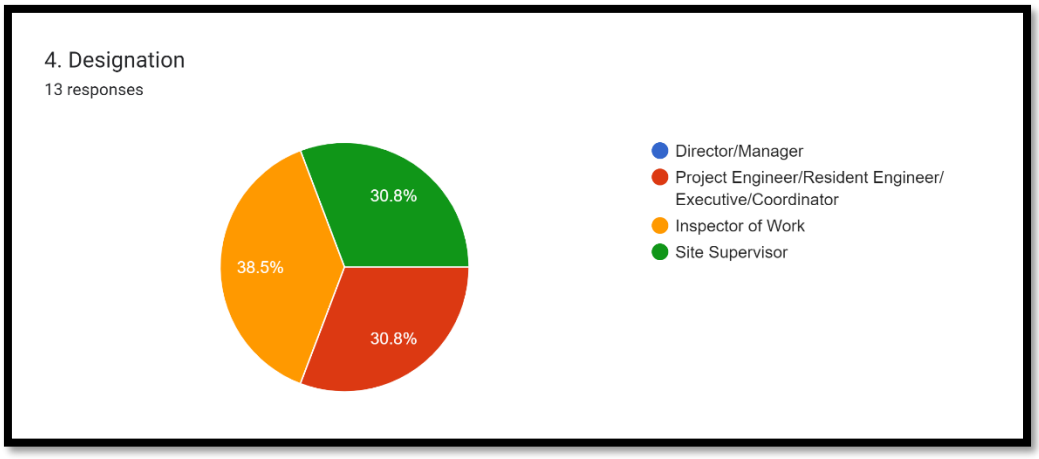


Figure 3.7 The number of respondents by designation

In Table 3.7 above, the number of respondents is an Inspector of Work with the majority registering a as much as 38.5%. Followed by the Project Engineer/Resident Engineer/Executive/Coordinator and Site Supervisor which has the percentage of 25%.

v. Work Experience

The last item for section A in the demographic data is the duration of current position, where there is various duration of current positions of less than 1 year, 2-5 years, 6-10 years, ≥11 years, and more than 1 year. Figure 3.8 and Table 3.8 below appointment pie chart illustration and table.

Table 3.8 The number of respondents by work experience

No	Work Experience	No respondent	Percentage (%)
1	Less than 1 year	0	0%
2	2-5 years	7	43.8%
3	6-10 years	8	50%
4	More than 11 years	1	6.3%
	Total	13	100%

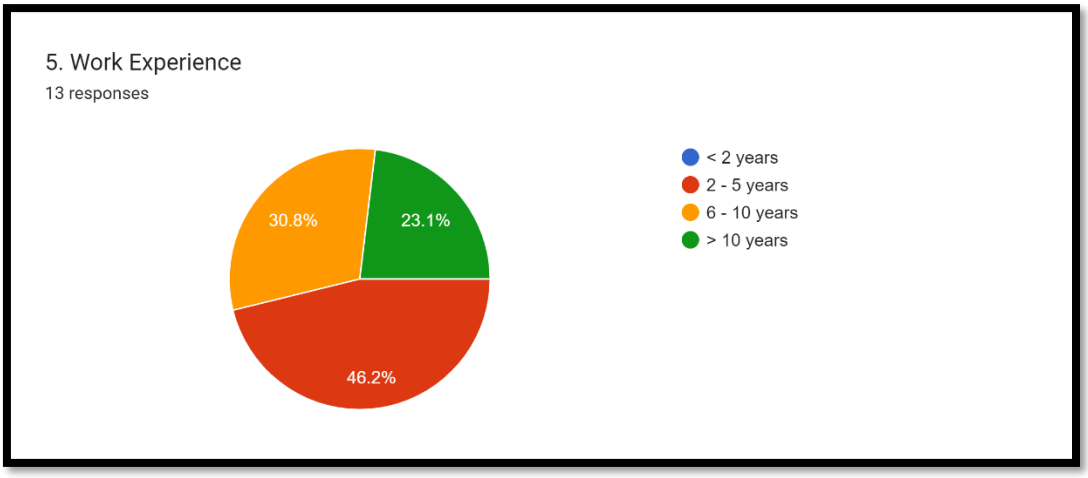


Figure 3.8 The number of respondents by work experience

3.11 Conclusion

The concluding chapter of the study focuses on the information and data collection strategy employed, summarizing the findings of the data analysis. It highlights details such as the study's location, the characteristics of the respondents, the research techniques utilized, and the interpretation of the collected data. Moreover, it emphasizes the progress made throughout the review process, particularly in terms of digital utilization, suggesting that the current state of digital use is superior to previous practices. Overall, the chapter underscores the preference for digital utilization and its advantages over traditional approaches.

Considering modern technology, the present method of identifying issues with rebar inspection via WhatsApp and dealing with irrelevant communications is evidently not beneficial, as indicated by the findings of surveys and interviews conducted. Furthermore, it is recommended that all industries, including the construction sector, adopt technology to support human efforts. Applications have proven to be valuable in enhancing established practices by significantly improving productivity, efficiency, and time management. The subsequent chapter will present a comprehensive explanation of the data analysis conducted in the study.

CHAPTER 4

RESULT

4.1 Introduction

The chapter primarily centers on data analysis, result interpretation, and discussions pertaining to the research project. The main goal of the project is to improve project management by enhancing the planning process for site work inspection. To accomplish this objective, the researchers have created the Rebar Inspection Using Augmented Reality Application, which functions as a solution to offer access to information concerning the specifics of reinforcement bar in beam. The project's specific objectives are outlined as follows:

i. Designing the Rebar Inspection Using Augmented Reality Application: The researchers aimed to design an application that enables users to access information related to site work inspection. This involves creating an intuitive and user-friendly interface that provides relevant details and updates.
ii. Developing the Rebar Inspection Using Augmented Reality Application: The project involves the development of the Rebar Inspection Using Augmented Reality Application using the BlippAR Website. The researchers would have worked on

implementing the necessary features and functionalities to ensure the application meets the requirements and objectives outlined.

iii. To evaluate the effectiveness of the Rebar Inspection Using Augmented Reality Application, the researchers conducted a usability evaluation. It is probable that they utilized a survey based on the Technology Acceptance Model (TAM) questionnaire, which included variables such as perceived ease of use, perceived usefulness, attitude towards technology usage, and behavioral intention to use. The collected data from the evaluation were then subjected to statistical analysis, including paired t-tests and mean comparisons, to assess the effectiveness of the application compared to existing methods.

By achieving these objectives, the researchers aimed to offer a comprehensive and efficient solution for effectively conduct inspection in construction projects. The implementation of the Rebar Inspection Using Augmented Reality Application is anticipated to enhance coordination, streamline access to information, and improve accuracy installation of reinforcement bar in beam.

4.2 Data Analysis

Next, the following section discussed the concerns with the previous conventional method. Respondents were instructed to circle the appropriate scores on a scale of 5 to 1. The scoring scale was as follows:

i. Strongly agree - 5
ii. Agree - 4
iii. Slightly agree - 3
iv. Disagree - 2
v. Strongly disagree – 1

Section B of the Pre- FYP questionnaires included questions about respondent's attitudes toward the existing method of Rebar Inspection work. Table 4.1 below contains the data for

Section B of the Pre-FYP questionnaires. Questions 1 (P.U 1) through 4 (P.U 4) collected information on the perceived effectiveness of the existing traditional procedure. According to the findings, most respondents believe that the present traditional strategy is ineffective. In response to question 1 (P.U 1) 7.1% of respondents slightly agree with the existing customary procedure, with % strongly disagreeing. For question 1 (P.U 2), 7.1% of respondents slightly agree, with 42.9% disagreeing. In response to question 1 (P.U 3), 14.3% of respondents slightly agree, with 21.4% disagreeing. Finally, for question 1 (P.U 4), 7.1% of respondents slightly agree, with 25% disagreeing and 8.3% strongly agree. This demonstrates that the current standard method is ineffective.

Questions 2 (P.E.U 1) to 2 (P.E.U 4) collected information on the existing method's perceived ease of use. According to the findings, the majority respondents believe that the present traditional strategy is ineffective. For issue 2 (P.E.U 1), 14.3 % of respondents slightly agree with the existing conventional procedure, 37.5% disagree and 21.4% strongly disagree. For question 2 (P.E.U 2), 42.9% of respondents disagreed that learning to utilize the existing method would be simple for users, while 7.1% is slightly agreed. For issue 2 (P.E.U 3), 66.7% of respondents slightly agree, with 14.3% disagreeing that the interaction with the existing technique was obvious and intelligible. Finally, for issue 2 (P.E.U 4), 37.5% of respondents disagree, while 21.4% strongly disagree and 14.3% strongly agree that it would be straight forward for users to manage their project using existing methods.

Questions 3 (I.U 1) through 3 (I.U 3) collected information on the intention to employ the existing conventional approach. According to the findings, the majority respondents believe that the present traditional strategy is ineffective. In response to question 3 (I.U 1), 42.9% of respondents disagree with the existing customary procedure, while 37.5% slightly agree and 14.3% agree. For question 3 (I.U 2), which is whether the user will utilize the existing method frequently, 37.5% disagree, while the remaining 21.4% strongly disagree and 14.3% strongly agree. Finally, on question 3 (I.U 3), 28.6% of respondents disagree, with 21.4% agree and 21.4% strongly agree. This demonstrates that people have little intention of using the existing method due to its complexities and are exploring for alternatives.

Questions 4 (A.U 1) to 4 (A.U 4) gave information on the current conventional method's actual application. According to the data, the majority respondents believe that the existing

traditional procedure is unsuitable for practical application. For question 4 (A.U 1), Existing approach makes work more fascinating, 42.9% of respondents disagree with the existing conventional way, 37.5% slightly agree. 35.7% disagree with question 4 (A.U 2), while 14.3% strongly agree with the Working with Existing Method is Fun. In response to question 4 (A.U 3), 42.9% of respondents disagree, while 14.3% agree. Finally, 14.3% of respondents strongly agree and agree with question 4 (A.U 4), while 7.1% slightly agree and 35.7% disagree and 28.6% strongly disagree. This proves that the existing conventional system is unsuitable for actual application, and an alternative is required to prepare progress of mega column work on the construction site.

Table 4.1 Existing Method Survey Data

No.	**Survey to identify effectiveness of Existing method on Project management at a construction site.**	**Strongly Agree**	**Agree**	**Slightly Agree**	**Disagree**	**Strongly Disagree**
		(5)	**(4)**	**(3)**	**(2)**	**(1)**
1	Using existing method would enhance my effectiveness in work (P.U 1)	14.3%	28.6%	7.1%	35.7%	14.3%
1	Using the existing method would improve my performance in work (P.U 2)	7.1%	35.7%	7.1%	42.9%	7.1%
1	Using existing method would increase my productivity (P.U 3)	21.4%	21.4%	14.3%	28.6%	7.1%
1	I found the existing method useful (P.U 4)	14.3%	14.3%	7.1%	35.7%	28.6%
2	I found existing method easy to use (P.E.U 1)	7.1%	21.4%	14.3%	35.7%	21.4%
2	Learning to use Existing method would be easy for me (P.E.U 2)	7.1%	28.6%	7.1%	42.9%	14.3%

No.	Survey to identify effectiveness of Existing method on Project management at a construction site.	Strongly Agree (5)	Agree (4)	Slightly Agree (3)	Disagree (2)	Strongly Disagree (1)
2	My interaction with Existing method was clear and understandable (P.E.U 3)	7.1%	14.3%	35.7%	42.9%	0.0%
2	It would be easy for me to manage my project using Existing method (P.E.U 4)	14.3%	14.3%	14.3%	37.5%	21.4%
3	I intend to use Existing method during my work (I.U 1)	7.1%	14.3%	35.7%	42.9%	0.0%
3	I will use Existing method often. (I.U 2)	14.3%	14.3%	14.3%	37.5%	21.4%
3	I intend to use Existing Method frequently. (I.U 3)	21.4%	21.4%	14.3%	28.6%	7.1%
4	Existing method makes work more interesting (A.U 1)	7.1%	14.3%	35.7%	42.9%	0.0%
4	Working with Existing method is fun. (A.U 2)	14.3%	14.3%	7.1%	35.7%	28.6%
4	I feel comfortable using Existing method (A.U 3)	7.1%	14.3%	35.7%	42.9%	0.0%
4	I look forward to those aspects of my job that require me to use existing method (A.U4)	14.3%	14.3%	7.1%	35.7%	28.6%

Section B of the Post - FYP questionnaire included questions about respondents' satisfaction with using the Rebar Inspection Using Augmented Reality Application to access information on the details of site preparation at the construction site. Table 4.2 below contains the data for Section B of the Post - FYP questionnaire. Questions 1(P.U 1) through 1 (P.U 4)

collected information on the perceived usefulness of accessing the Rebar Inspection Using Augmented Reality Application to get information on the intricacies of site preparation planning. According to the data, the majority respondents believe that the Rebar Inspection Using Augmented Reality Application is advantageous to project management on the construction site. For question 1 (P.U 1), 92.3% of respondents strongly agree with the Rebar Inspection Using Augmented Reality Application and 7.7% agree that the Rebar Inspection Using Augmented Reality Application method would improve their work effectiveness. Next, for question 1 (P.U 2), which is if using the Rebar Inspection Using Augmented Reality Application would boost users' work performance, 76.9% strongly agree, with 23.1% agreeing. For question 1 (P.U 3), 69.2% of respondents strongly agree, with 30.8% agreeing that adopting Rebar Inspection Using Augmented Reality Application would boost their productivity. Finally, for question 1 (P.U 4), 92.3% of respondents strongly agree, with 7.7% agreeing. This demonstrates the Rebar Inspection Using Augmented Reality Application's for project management on a construction site.

Questions 2 (P.E.U 1) to 2 (P.E.U 4) will offer statistics on the perceived ease of use of the Rebar Inspection Using Augmented Reality Application to project management on the construction site. According to the data, majority of respondents believe that the existing method is ineffective. For question 2 (P.E.U. 1), 84.6% of respondents strongly agree with the Rebar Inspection Using Augmented Reality Application, and 15.4% agree think that it is simple to use. For question 2 (P.E.U 2), saying that learning to utilize the Rebar Inspection Using Augmented Reality Application would be simple for users, the result was 92.3% strongly agree, with 7.7% agreeing. All respondents felt that using Rebar Inspection Using Augmented Reality Application was obvious and intelligible in response to question 2 (P.E.U 3). Finally, for question 2 (P.E.U. 4), 92.3% strongly agree, while 7.7% agree believe that it would be simple for users to manage their project using Rebar Inspection Using Augmented Reality Application.

Questions 3 (I.U 1) to 3 (I.U 3) offered information on the aim to use the Rebar Inspection Using Augmented Reality Application to allow visitors readily acquire information on the project's details and procedure. According to the findings, majority of respondents believe that the present key is ineffective. In response to question 3 (I.U. 1), 92.3% of respondents strongly agree and 7.7% agree with the Rebar Inspection Using

Augmented Reality Application. Then, in response to question 3 (I.U 2), all respondents agree that they will use the Rebar Inspection Using Augmented Reality Application frequently. Finally, for question 3 (I.U 3), 100% of respondents strongly agree think that Rebar Inspection Using Augmented Reality Application makes work more fascinating.

Questions 4 (A.U 1) to 4 (A.U 4) offered information on how the Rebar Inspection Using Augmented Reality Application was used for project management on the construction site. According to the data, the majority respondents believe the Rebar Inspection Using Augmented Reality Application is adequate for actual use. In response to question 4 (P.U 1), 100% of respondents strongly agree with the use of Rebar Inspection Using Augmented Reality Application, 0% agree, and 0% neither agree nor disagree. In response to question 4 (A.U 2), 100% strongly agree, while believe that working with Rebar Inspection Using Augmented Reality Application is enjoyable. Then, for question 4 (A.U 3), 100% of respondents strongly agree with that the users comfortable using the Rebar Inspection Using Augmented Reality Application. Finally, all respondents agree to use Rebar Inspection Using Augmented Reality Application for question 4 (A.U 4). 100% strongly agree and 0.0% agree. This proves that the Rebar Inspection Using Augmented Reality Application system is suitable for actual application, and an alternative is required to do inspection work on the construction site.

Table 4.2 Feedback after using Rebar Inspection using Augmented Reality Application

No.	Survey to identify effectiveness of Rebar Inspection Using Augmented Reality Application	Strongly Agree (5)	Agree (4)	Natural (3)	Disagree (2)	Strongly Disagree (1)
1	Using Rebar Inspection using Augmented Reality Application would enhance	92.3%	7.7%	0.0%	0.0%	0.0%

No.	Survey to identify effectiveness of Rebar Inspection Using Augmented Reality Application	Strongly Agree (5)	Agree (4)	Natural (3)	Disagree (2)	Strongly Disagree (1)
	my effectiveness in work (P.U 1)					
1	Using Rebar Inspection using Augmented Reality Application would improve my performance in work (P.U 2)	76.9%	23.1%	0.0%	0.0%	0.0%
1	Using Rebar Inspection using Augmented Reality Application would increase my productivity. (P.U 3)	69.2%	30.8%	0.0%	0.0%	0.0%
1	I found Rebar Inspection using Augmented Reality Application useful. (P.U 4)	92.3%	7.7%	0.0%	0.0%	0.0%
2	I found Rebar Inspection using Augmented Reality Application easy to use. (P.E 1)	84.6%	15.4%	0.0%	0.0%	0.0%
2	Learning to use Rebar Inspection using Augmented Reality Application would be easy for me. (P.E 2)	92.3%	7.7%	0.0%	0.0%	0.0%
2	My interaction with Rebar Inspection using Augmented Reality Application was clear and understandable. (P.E 3)	92.3%	7.7%	0.0%	0.0%	0.0%
2	It would be easy for me to manage my project Rebar	92.3%	7.7%	0.0%	0.0%	0.0%

No.	Survey to identify effectiveness of Rebar Inspection Using Augmented Reality Application	Strongly Agree (5)	Agree (4)	Natural (3)	Disagree (2)	Strongly Disagree (1)
	Inspection using Augmented Reality Application (P.E 4)					
3	I intend to Rebar Inspection using Augmented Reality Application during my work. (I.U 1)	92.3%	7.7%	0.0%	0.0%	0.0%
3	I will use Rebar Inspection using Augmented Reality Application often. (I.U 2)	92.3%	7.7%	0.0%	0.0%	0.0%
3	I intend Rebar Inspection using Augmented Reality Application frequently. (I.U 3)	100.0%	0.0%	0.0%	0.0%	0.0%
4	Rebar Inspection using Augmented Reality Application makes work more interesting. (A.U 1)	100.0%	0.0%	0.0%	0.0%	0.0%
4	Working with Rebar Inspection using Augmented Reality Application is fun. (A.U 2)	100.0%	0.0%	0.0%	0.0%	0.0%
4	I feel comfortable Rebar Inspection using Augmented Reality Application. (A.U 3)	100.0%	0.0%	0.0%	0.0%	0.0%
4	I look forward to those aspects of my job that require me to use Rebar Inspection using Augmented Reality Application (A.U 4)	100.0%	0.0%	0.0%	0.0%	0.0%

Table 4.3 shows respondent level of usability toward using existing method whereby analysis shows for all variables tested the mean score were less than 3.50 meaning that the usability level of existing method was low. Whilst Table 4.4 shows respondent level of usability toward using Rebar Inspection Using Augmented Reality Application whereby analysis shows for all variables tested the mean score were more than 4.00 meaning that the usage of Rebar Inspection Using Augmented Reality Application much easier compare with the existing method.

Table 4.3: Usability Level of existing method among respondents

Variables	Mean	Interpretation
Perceived Ease of Use	3.10	Low
Perceived Usefulness	2.90	Low
Attitude Towards Using Technology	2.70	Low
Behavioural Intention to Use	2.50	Low

Table 4.4 Usability Level of Rebar Inspection Using Augmented Reality Application among respondents

Variables	Mean	Interpretation
Perceived Ease of Use	4.80	High
Perceived Usefulness	4.90	High
Attitude Towards Using Technology	4.70	High
Behavioural Intention to Use	4.80	High

In order to evaluate the effectiveness of Rebar Inspection Using Augmented Reality Application in the project, a paired sample t test was performed. Results as shown in Table 4.5, respondent preferred using Rebar Inspection Using Augmented Reality Application whereby all variable measured, Perceived Ease of Use (Mean = 4.80), Perceived Usefulness (Mean = 4.90), Attitude Towards Using Technology (Mean = 4.70) and Behavioral Intention to Use (Mean = 4.80) were more higher compared with existing method, Perceived Ease of Use (Mean = 3.10), Perceived Usefulness (Mean = 2.90), Attitude Towards Using Technology (Mean = 3.10) and Behavioral Intention to Use (Mean = 3.10). A paired sample t-test found this difference to be significant for all variables being measured, the value of t of Perceived Ease of Use is 22.18 and the value of p is < .00001. The result is significant at p <

.05. The value of t of Perceived Usefulness is 16.75 and value of p is < .00001. The result is significant at p < .05. The value of t of Attitude Towards Using Technology is 21.52 and the value of p is < .00001. The result is significant at p < .05. The value of t of Behavioural Intention to Use is 15.65 and the value of p is < .00001. The result is significant at p < .05. This suggests that using Rebar Inspection Using Augmented Reality Application was much easier and resourceful compared with existing method. This mean that Rebar Inspection Using Augmented Reality Application was more effective compare with the existing method.

Table 4.5: Paired sample t-test

Pair	Paired Different Mean	t	Significant (two tailed)
Perceived Ease of Use - Existing Method	2.03	22.18	.000
Perceived Usefulness - Existing Method	2.03	16.75	.000
Attitude Towards Using Technology- Existing Method	2.03	21.52	.000
Behavioural Intention to Use- Existing Method	2.30	15.65	.000

4.3 Conclusion

The construction industry, despite its long history, has faced challenges in adopting cutting-edge technologies on job sites. Outdated processes and fragmented communication have hindered the sector, leading to inefficiencies in projects. This emphasizes the crucial role of technology in enhancing quality and productivity within the industry. Project managers acknowledge that integrating the right technologies can create a more productive work environment.

The findings from the survey of Sunway Construction SDN BHD employees, including engineers, site supervisors, and inspector of work (IOW), revealed a consensus that the Rebar Inspection Using Augmented Reality Application is more effective compared to the existing method. The current method of using paper for reference was considered outdated and difficult to manage. The respondents expressed a high level of agreement, with a mean score greater than 4.00, indicating that the Rebar Inspection Using Augmented Reality Application is user-friendly and that they have the intention to use it for obtaining information on reinforcement bars especially when doing inspection.

The effectiveness of the Rebar Inspection Using Augmented Reality Application was evaluated using a paired t-test, analyzed through the Social Science Statistics online website. The results demonstrated a significant difference between the application and the existing method, indicating that the Rebar Inspection Using Augmented Reality Application is not only more effective but also easier to use. Therefore, it is highly recommended for gaining all necessary information on reinforcement bars.

Overall, the construction industry recognizes the importance of technology in improving quality and productivity. The Rebar Inspection Using Augmented Reality Application presents a valuable solution to the challenges faced in the industry. It streamlines processes, reduces reliance on outdated methods such as paper, and enhances efficiency. Given these advantages, the application is highly recommended for use in construction site information management.

CHAPTER 5

CONCLUSION, DISCUSSION & SUGGESTION

5.1 Introduction

The primary objective of the study was to address the common issue of inadequate inspection methods for reinforcement bars by developing the Rebar Inspection Using Augmented Reality Application. This application was developed using the BlippAR Buildbuilder programming tool and its usability and effectiveness were evaluated among the staff of the company through an online survey.

The survey incorporated four variables derived from the Technology Acceptance Model (TAM) questionnaire: Perceived Ease of Use, Perceived Usefulness, Attitude Towards Using Technology, and Behavioral Intention to Use. The data collected from the survey were then analyzed using paired t-tests and mean calculations.

The findings from the paired t-test demonstrated a significant difference between the Rebar Inspection Using Augmented Reality Application and the existing method. This suggests that the application outperformed the existing method in terms of usability, indicating its effectiveness and superiority.

Based on these results, the study highly recommended the implementation of the Rebar Inspection Using Augmented Reality Application for managing and coordinating individuals and processes within construction projects. The application's enhanced usability and effectiveness make it a valuable tool for improving inspection work related to reinforcement bars, ultimately contributing to the success and efficiency of construction projects.

By implementing the Rebar Inspection Using Augmented Reality Application, contractors can overcome the challenges posed by inadequate methods and enhance their project management practices. This application serves as a comprehensive platform that integrates various crucial factors for effective construction management, including coordination, communication, and process management. It offers features that improve the ease of use, usefulness, and overall attitude towards adopting technology in construction projects.

The positive feedback received from the staff through the survey indicates the application's potential to streamline and optimize the management of construction projects. Its implementation can lead to improved efficiency, reduced errors, and enhanced coordination among team members involved in the inspection of reinforcement bars. By leveraging technology and addressing the limitations of traditional methods, contractors can benefit from a more streamlined and organized approach to construction management.

The survey results further validate the usability of the Rebar Inspection Using Augmented Reality Application, providing strong support for its adoption in the construction industry. By embracing this application, contractors can significantly improve project outcomes and address the challenges associated with inadequate inspection methods.

In conclusion, the study successfully developed and tested the Rebar Inspection Using Augmented Reality Application, demonstrating its superiority over existing methods in terms of usability. Its implementation is highly recommended to improve project management practices, enhance coordination, and mitigate the challenges posed by insufficient methods in inspection work. By leveraging this technology, contractors can achieve better project outcomes and establish a more efficient and effective construction process.

5.2 Discussion

To tackle the challenges faced by the company, proactive measures were taken, including the application of the design thinking process. As part of the empathy stage, the researcher engaged in interviews with various construction practitioners such as project managers, site engineers, site supervisors, inspector of work (IOW), suppliers, and consultants. This enabled a deep understanding of the challenges encountered in the construction industry and served as a foundation for developing a viable solution.

Based on the insights gained from the interviews, a mock-up of the proposed solution was created. This mock-up was then distributed among construction personnel for competence testing, ensuring that the solution met the required standards and addressed the identified challenges effectively. The feedback and input received from the construction personnel were invaluable in refining and improving the solution before its final handover to the company.

By employing the design thinking process and actively involving construction practitioners in the development and testing stages, a comprehensive and user-centric solution was crafted to address the company's challenges. This approach not only ensured that the solution was tailored to the specific needs of the construction industry but also increased the likelihood of successful implementation and acceptance among the company's personnel.

Two questionnaires were administered to collect feedback on both the traditional, outdated method used for inspecting beam reinforcement bars and the newly developed Rebar Inspection Using Augmented Reality Application. The analysis of the questionnaire responses revealed that the usability level of the existing method was notably low, as respondents expressed difficulties in effectively carrying out their inspection work using this approach.

Conversely, the feedback received regarding the Interactive Rebar Inspection Using Augmented Reality Application demonstrated that it was significantly easier to use compared to the previous method. The mean scores for key variables such as Perceived Ease of Use,

Perceived Usefulness, Attitude Towards Using Technology, and Behavioral Intention to Use were consistently higher for the application.

These findings highlight the superiority of the Rebar Inspection Using Augmented Reality Application in terms of usability and user satisfaction. The application's enhanced ease of use, perceived usefulness, positive attitude towards technology, and increased intention to use make it a highly preferred choice over the old-fashioned method for inspecting beam reinforcement bars.

According to the findings in Table 4, respondents preferred using Augmented Reality on reinforcement bars inspection, with all variables measured Perceived Ease of Use (Mean = 4.80), Perceived Usefulness (Mean = 4.90), Attitude Towards Using Technology (Mean = 4.70) and Behavioral Intention to Use (Mean = 4.80) being significantly higher than the existing method. Perceived Ease of Use (Mean - = 3.10), Perceived Usefulness (Mean = 2.90), Attitude Towards Using Technology (Mean = 2.70), and Behavioral Intention to Use (Mean = 2.50). A paired sample t-test revealed that this difference was significant for all variables studied. The value of t for Perceived Ease of Use is 22.18 and the value of p is < .00001.

The outcome is significant at p.05. Perceived Ease of Use has a t value of 22.18 and a p value of.00001. The outcome is noteworthy at p.05. The t value of Behavioral Intention to Use is 15.65, while the p value is.00001. significant at $p < .05$. The value of t of Perceived Usefulness is 16.75 and value of p is < .00001. The result is significant at $p < .05$. The value of t of Attitude Towards Using Technology is 21.52 and the value of p is < .00001. The result is significant at $p < .05$. This suggests that using Rebar Inspection Using Augmented Reality Application was much easier and resourceful compared with existing method. This mean that Rebar Inspection Using Augmented Reality Application was more effective compare with the existing method.

The Rebar Inspection Using Augmented Reality Application emerged as valuable assets for the company, particularly for its Quality Assurance and Quality Control (QAQC) department in effectively managing and ensuring the quality of work. The positive feedback received and the significant improvements observed through its implementation reinforced the recommendation for widespread utilization of the application within the company.

The application brought about enhanced organization, increased usefulness, and improved user-friendliness in the inspection processes. It eliminated the reliance on paper-based methods, streamlining and digitizing the workflow. With a reliable internet connection, personnel were able to access and stay updated on building site plans, fostering a more efficient and informed approach to their tasks.

The Rebar Inspection Using Augmented Reality Application, with its notable benefits and positive impact on quality control, emerged as an indispensable tool for the company. Its adoption promises to elevate the overall quality of work, boost productivity, and enable a more streamlined and technologically advanced approach to construction site inspections.

5.3 Suggestion/Recommendation

Based on the presented findings, the researcher proposes several recommendations to enhance the usage of the Rebar Inspection Using Augmented Reality Application and guide future actions:

1. Expand the Application Scope: Expanding the application's coverage beyond the Sunway Belfield construction site area to encompass other projects undertaken by the organization would bring numerous advantages and benefit a broader range of stakeholders.

2. Enhance Security Measures: To ensure the confidentiality of sensitive information handled by the application, it is imperative to enhance its security features. One crucial step is to implement robust access controls and establish a mandatory login system for users. By doing so, the application can protect the confidentiality of reinforcement bars data, allowing only authorized individuals to access and interact with the information.

3. Utilize Advanced Application Development Tools: In order to enhance the Rebar Inspection Using Augmented Reality Application, it is recommended to explore alternative software platforms beyond BlippAR Buildbuilder. Platforms such as

BlippAR SDK, Zappar, RE'FLEKT, Plattar, or Snap can offer more advanced features and capabilities, enabling users to develop applications with increased flexibility and functionality.By considering these alternative platforms, users can leverage a wider range of tools and technologies, allowing for the creation of a more robust and tailored application. Additionally, adopting these platforms presents an opportunity for users to acquire new skills, such as coding and blockchain integration, which can further enhance their expertise and expand their capabilities in the field of augmented reality application development.

4. Embrace Technology for Construction Excellence: Embracing technology is essential for the efficient delivery of high-quality construction projects. The implementation of the Rebar Inspection Using Augmented Reality Application holds immense potential for streamlining reinforcement bar inspection work progress on construction sites, resulting in significant time savings. Adopting such technological advancements not only improves the company's services but also enhances its competitiveness in the construction industry by attracting a larger user base. Furthermore, the utilization of advanced technology in construction activities can contribute to the overall economic growth of Malaysia. By staying at the forefront of technological innovation, the country can position itself favorably against other industrialized nations, establishing its presence as a leader in the construction sector. This heightened competitiveness on the global stage has the potential to attract investments, drive economic development, and create new opportunities for growth and advancement.

By incorporating the recommended measures, the company can unlock additional benefits and optimize the Rebar Inspection Using Augmented Reality Application. One of the key advantages is the improved project management across multiple sites. By expanding the application's coverage to various projects undertaken by the organization, it becomes a centralized platform for monitoring and tracking rebar inspection work progress. This enables better coordination, streamlined communication, and efficient resource allocation across different construction sites. Moreover, the implementation of strict access controls and

a login system ensures the confidentiality and security of sensitive information related to reinforcement bars. This safeguards the integrity of the data and prevents unauthorized access or tampering, reinforcing the trust and reliability of the application.

Additionally, by embracing technology and leveraging the advanced capabilities of the Rebar Inspection Using Augmented Reality Application, the company can enhance construction processes. Augmented reality provides a visual overlay of information onto the real-world environment, enabling engineers, site supervisors, and project managers to have a clear and accurate understanding of rebar placement. This reduces errors, minimizes rework, and improves overall construction efficiency.

Furthermore, the utilization of technology in construction activities can lead to enhanced outcomes and better project deliverables. The Rebar Inspection Using Augmented Reality Application ensures that reinforcement bar placement adheres to design specifications and industry standards, ultimately resulting in higher-quality construction projects. This not only improves customer satisfaction but also strengthens the company's reputation for delivering excellence.

In summary, by implementing the suggested measures, the company can optimize the Rebar Inspection Using Augmented Reality Application, leading to improved project management across multiple sites, heightened security of sensitive data, enhanced construction processes, and superior project outcomes. These advancements contribute to increased efficiency, better work quality, and ultimately, the company's overall success in the construction industry.

5.4 Conclusion

The study conducted at Sunway Construction SDN BHD revealed that the employees, including engineers, site supervisors, inspector of work (IOW), and project managers, unanimously agreed that the Rebar Inspection Using Augmented Reality Application was superior to the existing method. The current method, which relied on PDF drawings and paper as references and submissions, was considered outdated and challenging to manage. The employees found the application to be easy to use and expressed their intention to utilize it for obtaining information on the placement of reinforcement bars, as indicated by the high mean scores (>4.00).

To establish the effectiveness of the Rebar Inspection Using Augmented Reality Application, a paired t-test was conducted with the assistance of the Social Science Statistics online website. This statistical analysis revealed a significant difference between the application and the existing method, confirming that the application was not only more effective but also easier to use. This finding strongly supports the recommendation to use the application for managing all information related to construction inspection work progress concerning rebar placement.

Furthermore, the Rebar Inspection Using Augmented Reality Application is available as a mobile application, providing convenience and ease of use for all employees. This accessibility allows employees to access the application on their smartphones or tablets, making it readily available on-site, enhancing efficiency and productivity.

The researcher concludes that technology plays a crucial role in the construction business, facilitating the production of high-quality projects. By adopting the Rebar Inspection Using Augmented Reality Application, Sunway Construction SDN BHD can reap several benefits. Firstly, the company can reduce paper expenses by transitioning from physical drawings to digital representations. This not only saves costs but also contributes to environmental sustainability. Additionally, the application saves time by streamlining the inspection process, allowing employees to quickly, and accurately access information on rebar placement.

Moreover, the application enhances the overall work quality by providing a more systematic approach to managing construction inspection work progress. The digital platform ensures that accurate and up-to-date information is readily available to all relevant stakeholders, reducing the chances of errors or miscommunication. This leads to improved project outcomes and customer satisfaction.

Furthermore, the incorporation of technology, such as the Rebar Inspection Using Augmented Reality Application, can also attract more customers to the company's services. Clients are increasingly seeking construction companies that embrace innovative solutions, and by leveraging technology, Sunway Construction SDN BHD can showcase its commitment to delivering cutting-edge solutions.

Lastly, embracing technology in construction activities not only benefits the company but also contributes to the country's economic growth. By adopting advanced technological tools, Malaysia can keep pace with other successful countries worldwide in the construction sector. This positions Malaysia as a competitive player in the global market and attracts foreign investment, ultimately driving economic development and creating job opportunities.

In summary, the study's findings highlight the superiority of the Rebar Inspection Using Augmented Reality Application compared to the existing method. The application's ease of use, effectiveness, and potential for cost and time savings make it a valuable tool for Sunway Construction SDN BHD. By leveraging technology, the company can enhance work quality, attract more customers, and contribute to Malaysia's economic growth in the construction sector.

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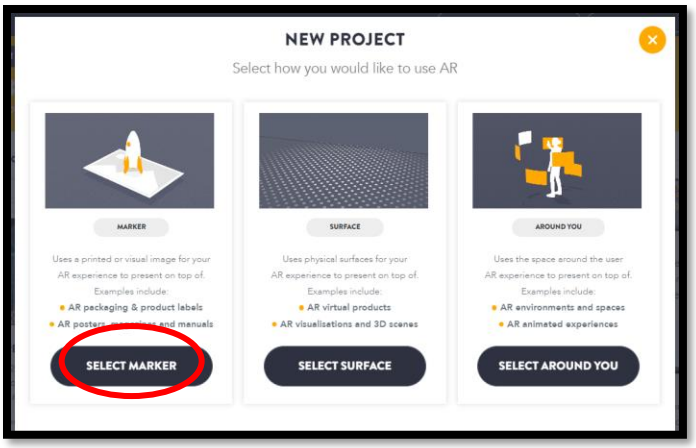
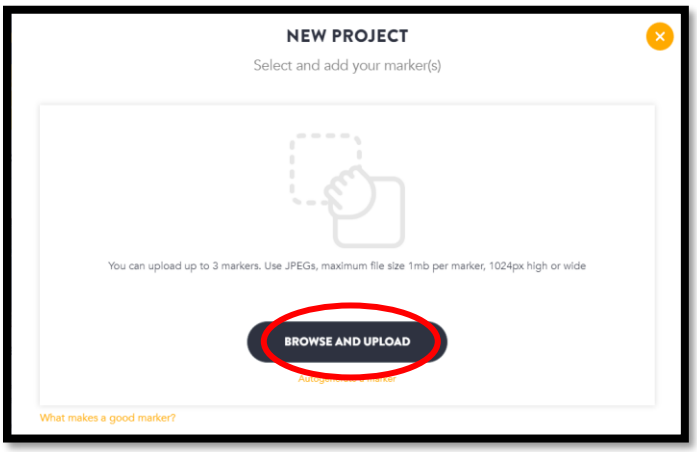
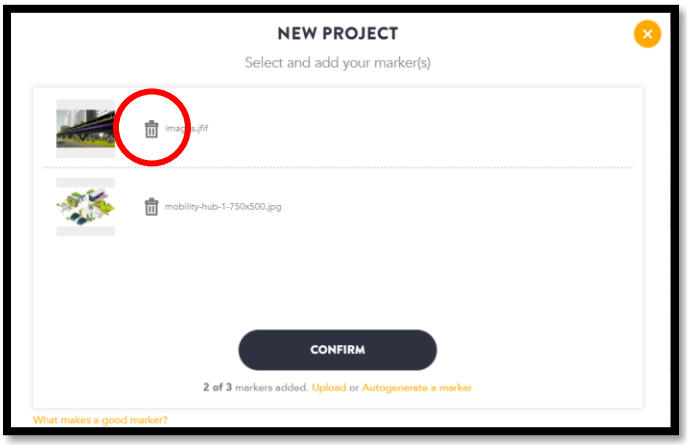
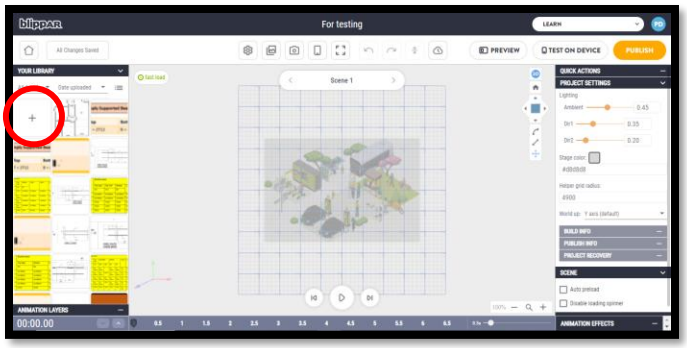
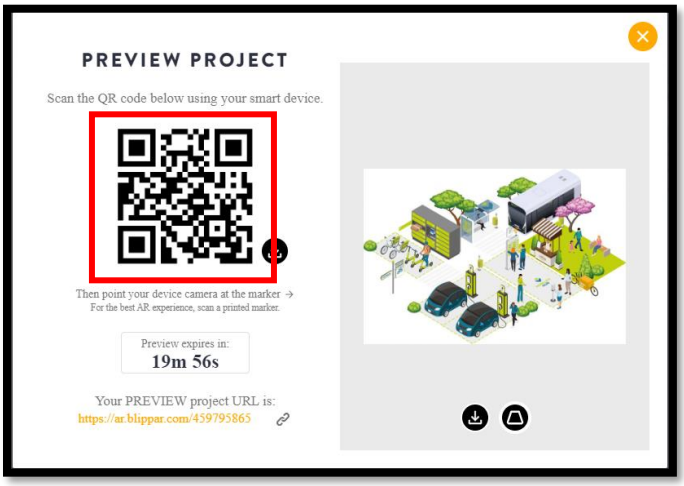
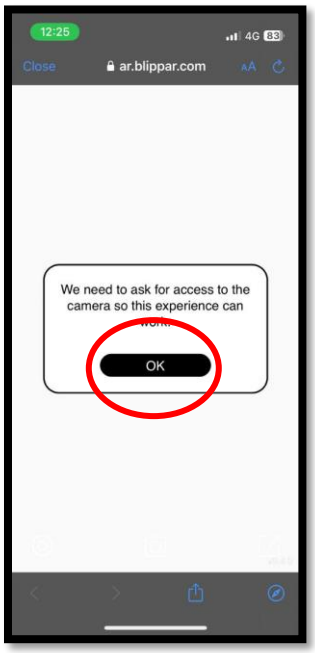
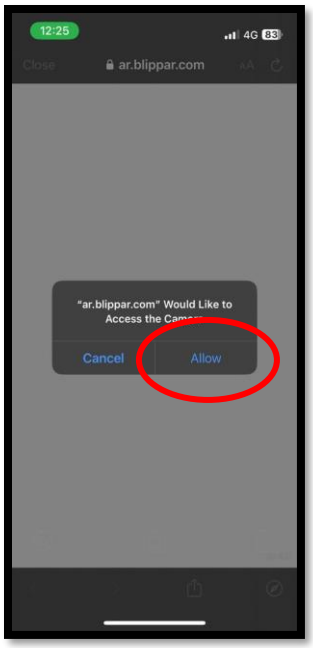
APPENDIX 1

DEVELOPMENT OF APPLICATION SYSTEM

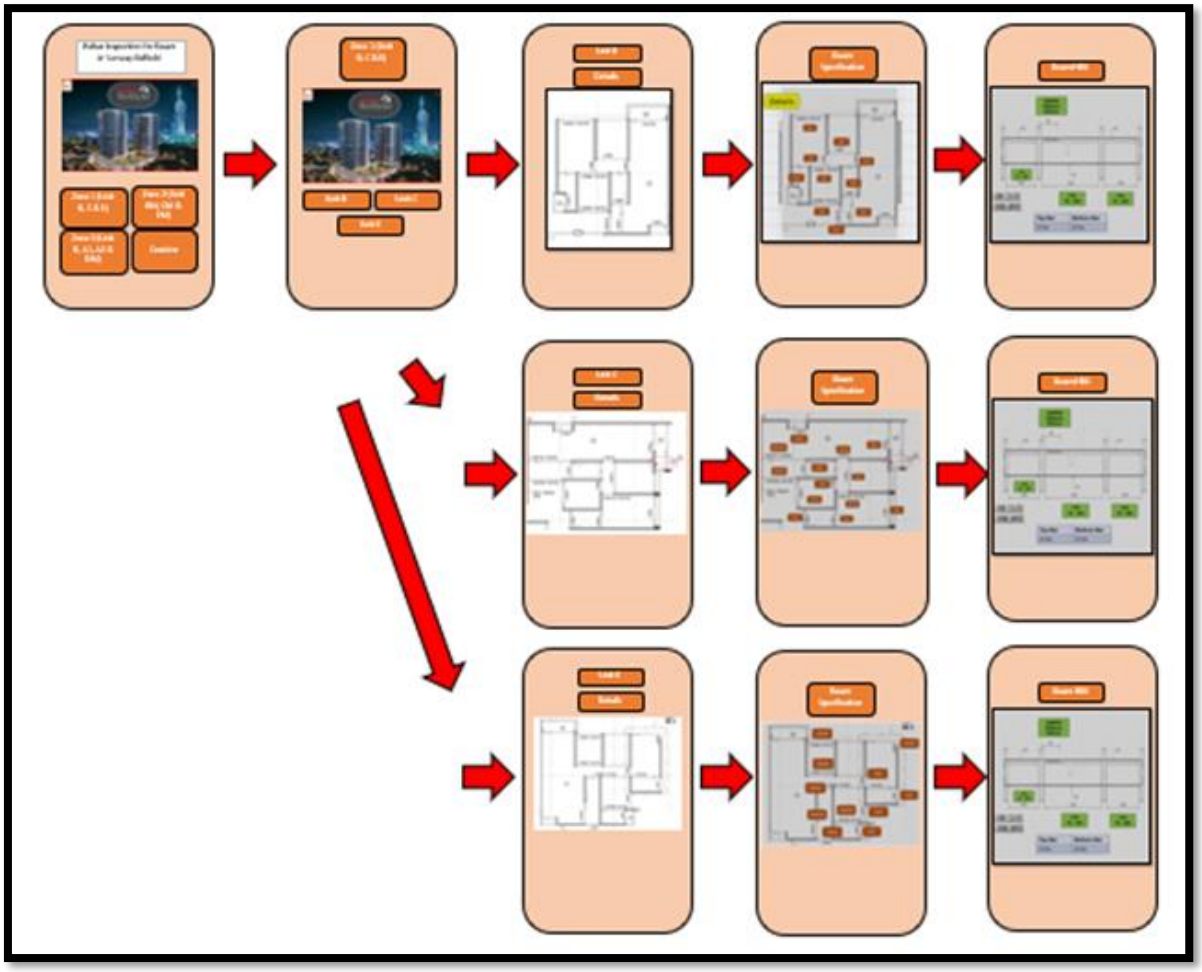
Prototype	Explanation
	Login to BlippAR. Click 'Select Marker' tab as shown in the image on the left.
	Click 'Browse and Upload' markers Choose the desired marker you wish to upload. It can alternatively 'Drag and Drop' your marker as shown in the image above. Up to 3 markers images can be tracked one at a time.
	Click 'Browse and upload' markers or alternatively 'drag and drop' desired marker in the section as shown in image. The uploaded markers can be seen in the 'Manage Marker' section. Click on the bin icon to delete an uploaded marker as shown in the image below. After that, click Confirm.

Prototype	Explanation
	Upload all information of the Sequence for loading bay.
	To preview your project, scan the QR Code. Scan your photo by clicking on the icon. Success to access blippAR Able to access all information that had be upload on BlippAR
	After Scan the QR Code on your Smartphone, it will directly access to BlippAR application. Click ‘Ok’ on the application to continue review the content.

Prototype	Explanation
	Click 'Allow' to access camera on that BlippAR application.
	Click 'Allow' on the screen to continue preview the content in the application.

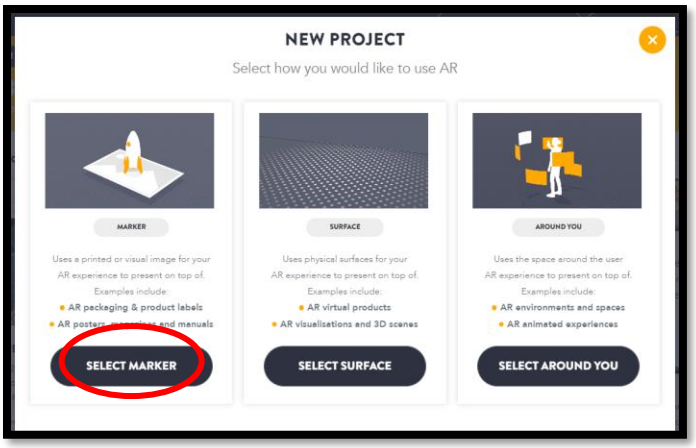
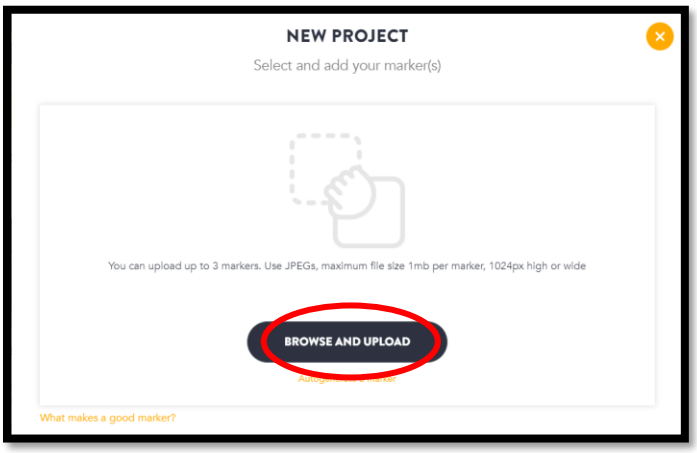
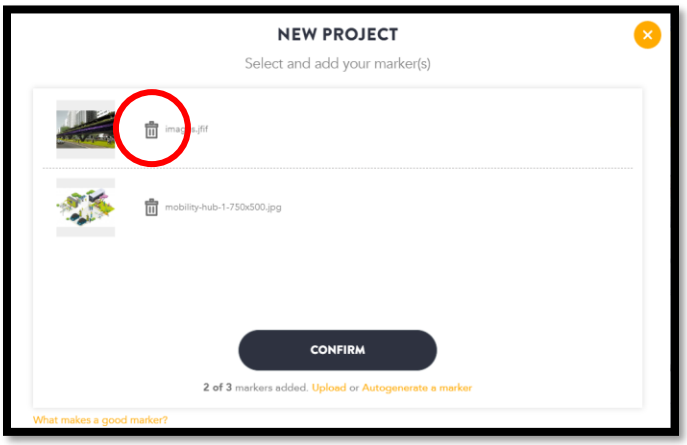
APPENDIX 2

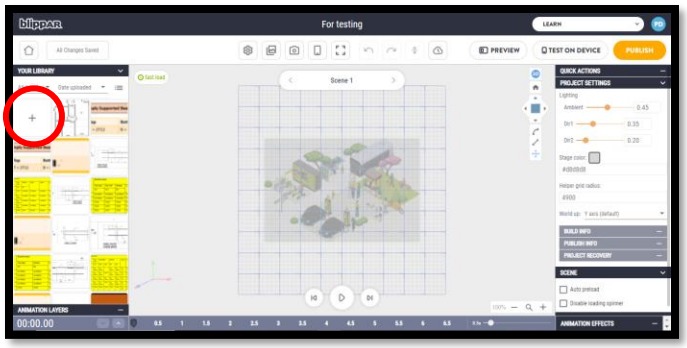
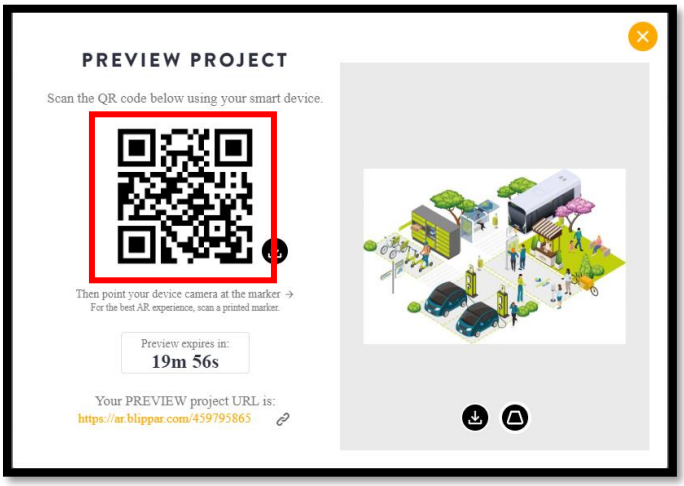
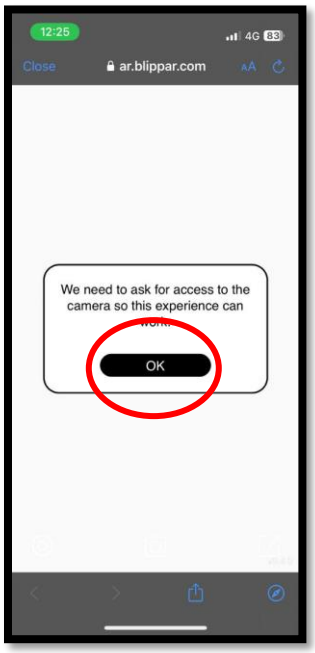
ARCHITECTURE DIAGRAM OF THE APPLICATION

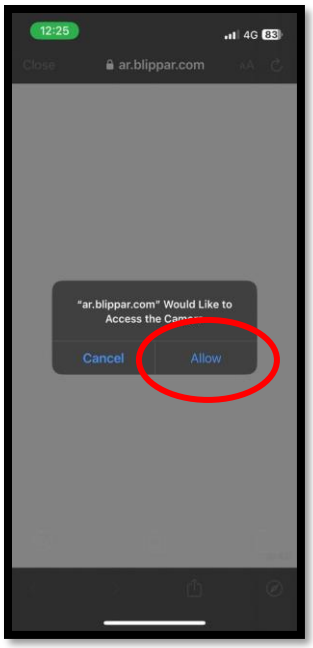
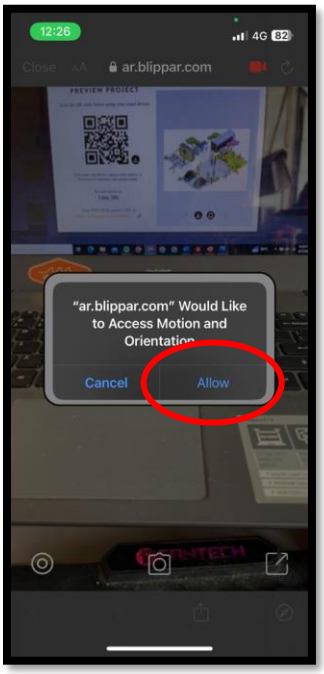


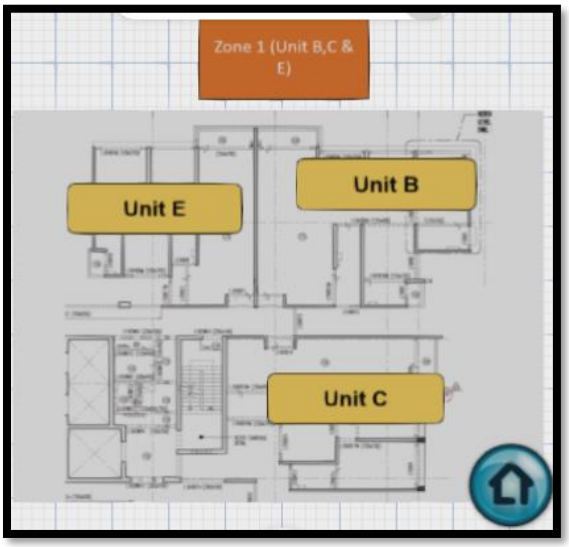
APPENDIX 3

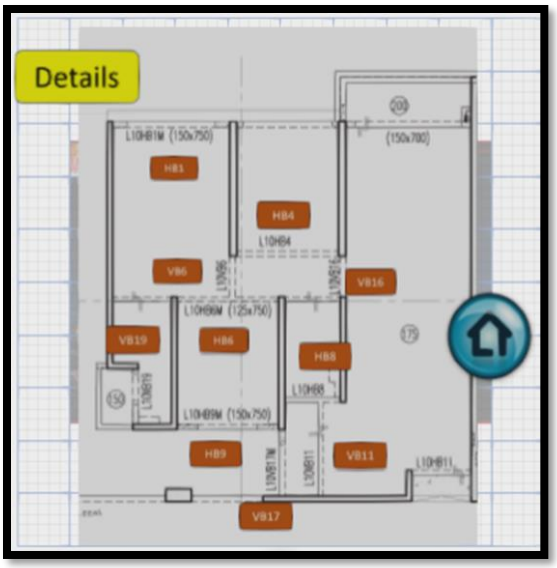
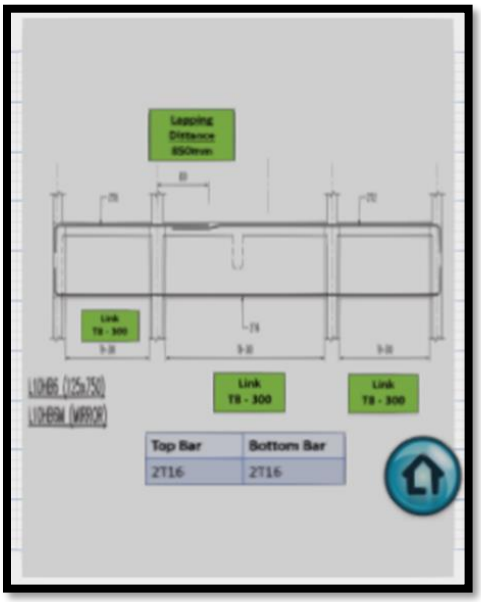
USAGE MANUAL OF REBAR INSPECTION USING AUGMENTED REALITY APPLICATION

Prototype	Explanation
	Login to BlippAR. Click 'Select Marker' tab as shown in the image on the left.
	Click 'Browse and Upload' markers Choose the desired marker you wish to upload. It can alternatively 'Drag and Drop' your marker as shown in the image above. Up to 3 markers images can be tracked one at a time.
	Click 'Browse and upload' markers or alternatively 'drag and drop' desired marker in the section as shown in image. The uploaded markers can be seen in the 'Manage Marker' section. Click on the bin icon to delete an uploaded marker as shown in the image below. After that, click Confirm.

Prototype	Explanation
	Upload all information of the Sequence for loading bay.
	To preview your project, scan the QR Code. Scan your photo by clicking on the icon. Success to access blippAR Able to access all information that had be upload on BlippAR
	After Scan the QR Code on your Smartphone, it will directly access to BlippAR application. Click ‘Ok’ on the application to continue review the content.

Prototype	Explanation
	Click 'Allow' to access camera on that BlippAR application.
	Click 'Allow' on the screen to continue preview the content in the application.

Prototype	Explanation
	The first preview will show this content which has 3 zoning areas and for google form. 1. Zone 1 (Units B, E, and C) 2. Zone 2 (BM, EM, and CM Units) 3. Zone 3 (Unit D, A1, A2 and DM) 4. Google form after checking.
	Click on Zone 1 button, it will directly show this content which is showing the type of units.

Prototype	Explanation
	Click on button “Unit E” and all the beam detailing will pop up just as shown in the picture.
	Click on the beam detailing button, it will directly show all the information needed for the beam. Click “Home button” when inspection for the beam is done.

APPENDIX 4

QUESTIONNAIRE (PRE)

Section 1 of 6

Rebar Inspection Using Augmented Reality Application

A part of my study of Final Year Project for Bachelor of Civil Engineering Technology (BCT) at Politeknik Ungku Omar (PUO), Ipoh, Perak, my name is Phoebe Anak Danny (01BCT20F3001) and I am conducting a survey to identify effectiveness of the Existing method on inspection for site at the construction site.

1. Gender *

- ○ Male
- ○ Female

2. Age *

- ○ 20 - 30 years
- ○ 31 - 40 years
- ○ 41 - 50 years

3. Organization (Company) *

Short answer text

4. Designation *

- ○ Director/Manager
- ○ Project Engineer/Resident Engineer/Executive/Coordinator
- ○ Inspector of Work
- ○ Site Supervisor
- ○ Other...

5. Work Experience *

- ○ < 2 years
- ○ 2 - 5 years
- ○ 6 - 10 years
- ○ > 10 years

Section 2 of 6

Section B

Questions 1 to Question 4 are outlined in the table below.
Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

Question 1 = Effectiveness Category (Perceived Usefulness)

Using Existing method would enhance my effectiveness in work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Using Existing method would improve my performance in work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Using Existing method would increase my productivity. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I found Existing method useful. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 3 of 6

Question 2: Effectiveness Category (Perceived Ease of Use)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

I found Existing method easy to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Learning to use Existing method would be easy for me. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

My interaction with Existing method was clear and understandable *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

It would be easy for me to manage my project using Existing method. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 4 of 6

Question 3: Effectiveness Categories (Intention to Use)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

I intend to use Existing method during my work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I will use Existing method often. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I intend to use Existing Method frequently. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 5 of 6

Question 4: Effectiveness Category (Attitude Toward Using)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

Existing method makes work more interesting *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Working with Existing method is fun. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I feel comfortable using existing methods *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I look forward to those aspects of my job that require me to use Existing method. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

APPENDIX 5

QUESTIONNAIRE (POST)

Section 1 of 6

Rebar Inspection Using Augmented Reality Application

A part of my study of Final Year Project for Bachelor of Civil Engineering Technology (BCT) at Politeknik Ungku Omar (PUO), Ipoh, Perak, my name is Phoebe Anak Danny (01BCT20F3001) and I am conducting a survey to identify effectiveness of the Existing method on inspection for site at the construction site.

1. Gender *

- ○ Male
- ○ Female

2. Age *

- ○ 20 - 30 years
- ○ 31 - 40 years
- ○ 41 - 50 years
- ○ 51 - 60 years
- ○ 61 and above

3. Organization (Company) *

Short answer text

4. Designation *

- Director/Manager
- Project Engineer/Resident Engineer/Executive/Coordinator
- Inspector of Work
- Site Supervisor
- Other...

5. Work Experience *

- < 2 years
- 2 - 5 years
- 6 - 10 years
- > 10 years

Section 2 of 6

Section B

Questions 1 to Question 4 are outlined in the table below.
Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

Question 1 = Effectiveness Category (Perceived Usefulness)

Using Rebar Inspection using Augmented Reality Application would enhance my effectiveness in work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Using Rebar Inspection using Augmented Reality Application would improve my performance in work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Using Rebar Inspection using Augmented Reality Application would increase my productivity. *

1	2	3	4	5

I found Rebar Inspection using Augmented Reality Application useful. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 3 of 6

Question 2: Effectiveness Category (Perceived Ease of Use)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

I found Rebar Inspection using Augmented Reality Application easy to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Learning to use Rebar Inspection using Augmented Reality Application would be easy for me. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

My interaction with Rebar Inspection using Augmented Reality Application was clear and understandable *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

It would be easy for me to manage my project using Rebar Inspection using Augmented Reality Application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 4 of 6

Question 3: Effectiveness Categories (Intention to Use)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

I intend to use Rebar Inspection using Augmented Reality Application during my work *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I will use Rebar Inspection using Augmented Reality Application often. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I intend to use Rebar Inspection using Augmented Reality Application frequently. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Section 5 of 6

Question 4: Effectiveness Category (Attitude Toward Using)

Fill the form according to choices that given below.
(1: Strongly disagree 2: Disagree 3: Slightly Agree 4: Agree 5: Strongly agree)

Rebar Inspection using Augmented Reality Application makes work more interesting *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Working with Rebar Inspection using Augmented Reality Application is fun. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I feel comfortable using Rebar Inspection using Augmented Reality Application. *

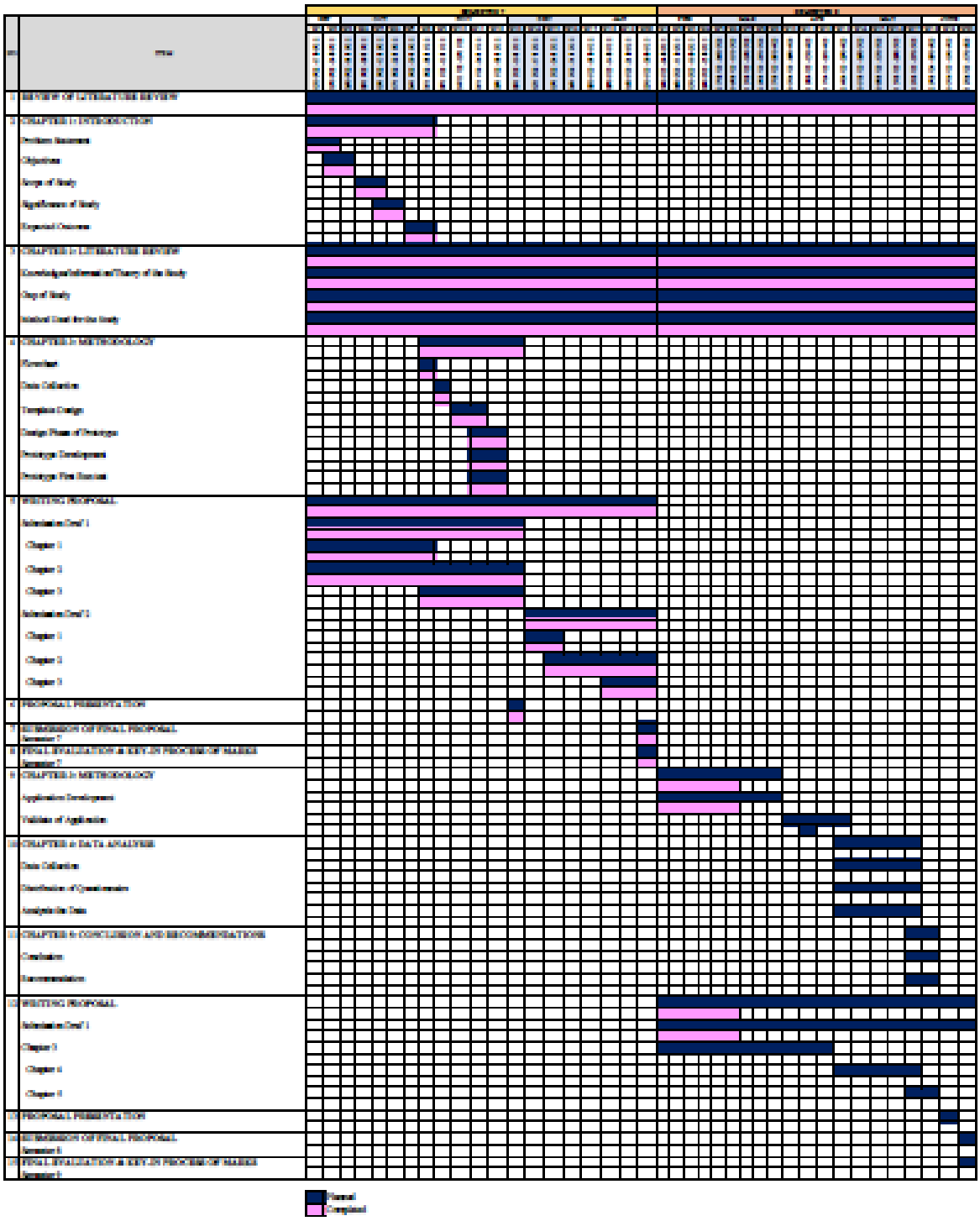
	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I look forward to those aspects of my job that require me to use Rebar Inspection using Augmented Reality Application. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

APPENDIX 6

GANTT CHART



APPENDIX 7

INDUSTRY APPRECIATION LETTER OF PRODUCT

SUNWAY CONSTRUCTION

JABATAN KEJURUTERAAN AWAM,
Politeknik Ungku Omar,
Jalan Rusa Mahadi,
31400 Ipoh,
Perak Darul Ridzuan.
(Attn. Dr Rufaizal Bin Che Mamat)

Date: 02nd June 2023

Dear Sir,

THE PROPOSED REBAR INSPECTION USING AUGMENTED REALITY APPLICATION AT SUNWAY BELFIELD PROJECT. [Work-Based Learning Program (WBL)]

The duration of her involvement was from September 12, 2022, to June 3, 2023, as part of her Bachelor's Degree in Civil Engineering Technology with Honors. This letter certifies that Ms. Phoebe Anak Danny (Student ID: 01BCT20F3001) actively participated in a Work-Based Learning (WBL) Programme at Sunway Construction SDN BHD's Sunway Belfield site.

During her tenure at Sunway Construction SDN BHD, Ms. Phoebe Anak Danny undertook the development of an innovative application called "Rebar Inspection Using Augmented Reality" for her Final Year Project (FYP). This application was specifically designed to facilitate the inspection of beam reinforcement bars at the Sunway Belfield site. By providing information and details on the rebar through augmented reality, this application significantly reduces time, paper usage, costs, and enhances productivity during on-site inspections.

The Rebar Inspection Using Augmented Reality application has been successfully implemented and utilized during her internship period. Its effectiveness has been evident in terms of saving time, reducing costs, and promoting a shift towards a paperless working environment.

Yours sincerely,

MUHAMMAD GHAFFAR GHAZALI
Project Engineer

cc: Lee Yung Hui – Assistant Manager

SUNWAY CONSTRUCTION SDN BHD (271754-V)
(A member of Sunway Construction Group)
Level 8, Menara Sunway, Jalan Lagoon Timur, Bandar Sunway, 47500 Petaling Jaya, Selangor Darul Ehsan, Malaysia.
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