POLITEKNIK UNGKU OMAR

AUGMENTED REALITY MOBILE APPLICATION FOR ENHANCING 3D VISUALIZATION IN CONSTRUCTION PROJECTS (ARCHITECT3D)

MUUGESH RAO A/L NAGES RAO

(01BCT21F3023)

CIVIL ENGINEERING DEPARTMENT

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A project report submitted to Civil Engineering Department in partial fulfillment of the requirement of the award of the Bachelor of Civil Engineering Technology with Honours

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SESSION II 2023/2024

DECLARATION OF ORIGINAL AND OWNERSHIP

AUGMENTED REALITY MOBILE APPLICATION FOR ENHANCING 3D VISUALIZATION IN CONSTRUCTION PROJECTS (ARCHITECT3D)

1. I, **MUUGESH RAO A/L NAGES RAO (991102086379)** a final-year student pursuing a **Bachelor of Civil Engineering Technology** at the **Civil Engineering Department, Politeknik Ungku Omar**.

2. I acknowledge that 'The Above Project' and the intellectual property contained therein are the work of my original work/invention without taking or imitating any intellectual property from any other party.

3. I agree to transfer ownership of the intellectual property of the 'Project' to the Politeknik Ungku Omar to meet the requirements for the award of the **Bachelor of Civil Engineering Technology** to us.

Made and truly acknowledged by the said;	)
MUUGESH RAO A/L NAGES RAO	) ....
(IC No.: 991102-08-6379),	) MUUGESH RAO A/L NAGES RAO

In front of me, Ms. SAMIKHAH BINTI MUHAMMAD	
@ MUNIR	) ....
as project supervisor on date:	)

APPRECIATION

In recognizing the paramount contributions to this project, the author extends deep appreciation to Ms. Samikhah Binti Muhammad @ Munir, the esteemed project supervisor. Ms. Samikhah's unwavering support and invaluable guidance were transformative, shaping the very trajectory of this research endeavor. Her keen insights not only enriched the project but also served as a constant source of inspiration throughout its duration, elevating the work to new heights.

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In conclusion, this acknowledgment serves as a heartfelt tribute to the collaborative spirit and shared commitment that fueled the success of this project. The author is deeply grateful for the privilege of working alongside such dedicated and talented individuals, whose collective contributions have left an indelible mark on the accomplishment of this significant research endeavor.

ABSTRACT

The construction industry in Malaysia has undergone transformative advancements with the onset of Industry Revolution 4.0 (IR 4.0). In this era, technology, particularly Augmented Reality (AR), has played a pivotal role in enhancing the quality and productivity of construction projects, aligning with sustainable development goals (SDGs) by promoting industry innovation and infrastructure (SDG 9) and contributing to sustainable cities and communities (SDG 11). The Sunway Medical Centre Ipoh (SMCI) project faces challenges stemming from the reliance on 2D drawings in the onsite construction process. This practice limits visualization for onsite field personnel, leading to difficulties in accurately interpreting the drawings, resulting in rework, increased costs, and extended timelines. The study aims to develop an AR mobile application named ARchitect3D using Unity software to address the lack of 3D visualization. The effectiveness of the developed mobile application was tested through quantitative study and analyzed using SPSS Statistics software. The reliability test resulted in a score of 0.968, indicating that the responses are reliable and reflect a true measure of the application's effectiveness. Following this, a paired sample test yielded an average mean score of 3.83 with a standard deviation of 0.449, indicating significantly higher effectiveness of the developed application. The study concludes with recommendations for further research and implementation, emphasizing the importance of continued exploration and refinement of AR-based approaches to advance the ongoing digital transformation within the construction industry.

Keywords: 3D visualization, augmented reality, construction waste, effectiveness

ABSTRAK

Industri pembinaan di Malaysia telah mengalami kemajuan transformasi dengan permulaan Revolusi Industri 4.0 (IR 4.0). Dalam era ini, teknologi, khususnya Realitas Berimbuh atau lebih dikenali sebagai *Augmented Reality* (AR), telah memainkan peranan penting dalam meningkatkan kualiti dan produktiviti projek pembinaan, sejajar dengan Matlamat Pembangunan Mampan (SDGs) dengan mempromosikan inovasi industri dan infrastruktur (SDG 9) serta menyumbang kepada bandar dan komuniti mampan (SDG 11). Projek Sunway Medical Centre Ipoh (SMCI) menghadapi cabaran dari penggunaan lukisan 2D dalam proses pembinaan di tapak. Amalan ini menyekat visualisasi untuk kakitangan lapangan yang menyebabkan kesulitan dalam menafsir dengan tepat lukisan-lukisan tersebut, yang akhirnya membawa kepada kerja semula, peningkatan kos serta sisa binaan, dan jangka masa yang dilanjutkan. Kajian ini bertujuan untuk mengembangkan aplikasi mudah alih AR (ARchitect3D) dengan menggunakan perisian Unity untuk mengatasi kekurangan visualisasi 3D di tapak bina SMCI. Keberkesanan aplikasi mudah alih yang dibangunkan diuji melalui kajian kuantitatif dan dianalisis menggunakan perisian SPSS Statistics. Ujian kebolehpercayaan menghasilkan skor 0.968, menunjukkan bahawa respons boleh dipercayai dan mencerminkan ukuran sebenar keberkesanan aplikasi tersebut. Tambahan pula, ujian sampel berpasangan menghasilkan skor min purata 3.83 dengan sisihan piawai 0.449, menunjukkan keberkesanan aplikasi yang dibangunkan secara signifikan lebih tinggi. Kajian ini disimpulkan dengan cadangan untuk penyelidikan dan pelaksanaan lanjut, menekankan kepentingan terus meneroka dan menyempurnakan pendekatan berasaskan AR untuk memajukan transformasi digital berterusan dalam industry pembinaan.

Kata kunci: visualisasi 3D, realitas berimbuh, sisa binaan, keberkesanan

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LIST OF ABBREVIATION

AR	Augmented Reality
3D	Three Dimensional
BIM	Building Information Modelling
GA	General Assurance
IDE	Integrated Development Environment
IR 4.0	Industry Revolution 4.0
SDG	Sustainable Development Goals
SDK	Software Development Kit
SMCI	Sunway Medical Centre Ipoh

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

The construction industry in Malaysia stands as a dynamic and vital sector contributing significantly to the country's economic development (Khan et al., 2014). Recognized for its rapid growth and diverse range of projects, the industry plays a crucial role in shaping Malaysia's modern infrastructure. The sector encompasses a wide spectrum, from residential and commercial developments to large-scale infrastructure projects, reflecting the nation's commitment to urbanization and economic progress. Malaysia's construction industry is known for embracing technology, with a growing emphasis on adopting Building Information Modelling (BIM) and other advanced tools to enhance project efficiency and accuracy. As the nation continues to urbanize and embark on ambitious infrastructure initiatives, the construction industry remains a key driver of economic growth, creating employment opportunities and fostering innovation in the built environment.

Construction drawings serve as the foundational communication tool in the construction industry. These detailed, two-dimensional representations convey critical information to various stakeholders involved in a construction project, including architects, engineers, contractors, and regulatory authorities. In Malaysia, where a burgeoning construction sector contributes significantly to economic growth, the accuracy and clarity of construction drawings are paramount. These drawings outline architectural plans, structural details, and other essential specifications, acting as a blueprint that guides the construction process (Duston et al., 2005). Effective interpretation of construction drawings minimizes misunderstandings, reduces errors, and ensures seamless collaboration among the diverse teams working on a project.

The adoption of Building Information Modeling (BIM) has gained momentum in Malaysia's construction industry, marking a shift towards more sophisticated and integrated project management (Bui et al., 2016). BIM goes beyond traditional two-dimensional (2D) drawings by creating a comprehensive digital representation of a building's entire lifecycle. In Malaysia, where large-scale infrastructure projects are on the rise, BIM offers benefits such as improved collaboration, clash detection, and efficient project coordination. The ability to integrate multiple dimensions of data in a centralized platform enhances decision-making, mitigates risks, and ultimately contributes to the successful delivery of construction projects within stipulated timelines and budgets.

In the dynamic landscape of Malaysian construction sites, the importance of three-dimensional (3D) visualization cannot be overstated. Traditional 2D drawings, while essential, often fall short in conveying the intricacies of three-dimensional structures. 3D visualization tools provide a holistic perspective, allowing stakeholders to virtually walk through the project before physical construction begins. This immersive experience aids in better understanding spatial relationships, identifying potential clashes, and refining design details. The visual clarity offered by 3D models facilitates effective communication and decision-making, reducing the likelihood of errors and rework. In a country where urban development is rapidly evolving, the incorporation of 3D visualization in construction sites aligns with the industry's need for precision and efficiency.

As Malaysia's construction industry continues to evolve, the integration of advanced technologies such as BIM and 3D visualization is paramount. Construction drawings remain a foundational element, providing the basis for effective communication and collaboration. The adoption of BIM enhances project management capabilities, while 3D visualization tools offer unprecedented clarity and insight into construction projects. Together, these elements contribute to the efficiency, accuracy, and success of construction endeavours in Malaysia, positioning the industry for sustained growth and innovation.

1.2 PROBLEM STATEMENT

Construction sites frequently encounter difficulties stemming from the absence of comprehensive 3D views throughout the building process. Typically, at the SMCI project site, engineers, site supervisors, and contractors receive drawings in a 2D format, generated using software like AutoCAD and other 2D drawing tools. This practice not only limits visualization, making it challenging for them to accurately interpret complex architectural or engineering designs, leading to rework as shown in Figure 1.1, but it also contributes to significant paper usage due to the necessity of providing hard copies of 2D drawings compared to 3D drawing models.

Figure 1.1: Rework Due to Drawing Misinterpretation

Rework not only entails additional costs but also contributes to increased construction waste and extended project timelines. The financial implications are substantial, as resources are expended on rectifying errors that could have been mitigated with a clearer understanding of the initial design. Moreover, the environmental impact is noteworthy, given the escalated consumption of construction materials and the generation of additional waste. Furthermore, the project timeline is adversely affected by the need for rework, causing delays that can cascade into a series of interconnected challenges and affecting overall project efficiency.

1.3 OBJECTIVE

The aim of this study is to develop an Augmented Reality (AR) mobile application designed to address specific challenges, particularly the lack of visualization and misinterpretation of 2D drawings at the SMCI project site.

The objectives of this study are as follows:

a. To identify the client needs to overcome the problems on SMCI project site.
b. To develop ARchitect3D mobile application using Unity software.
c. To evaluate the effectiveness of Architect3D mobile application.

1.4 SCOPE OF STUDY

This study primarily focuses on addressing issues occurring at SMCI project site, a significant ongoing project within Sunway Construction Group Berhad (SunCon). The SMCI project entails the development of a state-of-the-art medical center, comprising an eight-story hospital building with an additional basement level dedicated to parking facilities. The project holds an estimated value of RM150 million and is designed to accommodate 200 beds, with a substantial gross floor area spanning 46,207 square meters. The project site is situated at Lot 544655, Off Persiaran Sunway, Sunway City Ipoh, 31150 Ipoh, Perak as shown in Figure 1.2.

Figure 1.2: SMCI Project Site Location

1.5 SIGNIFICANCE OF STUDY

The development of ARchitect3D, an innovative AR mobile application, hold significant implications for the construction industry especially in SMCI project site, aligning with several Sustainable Development Goals (SDGs) outlined by the United Nations for the year 2030.

One of the primary contributions of ARchitect3D is its capacity to overcome the limitations of traditional 2D General Assurance (GA) drawings. By seamlessly integrating 3D models into these drawings through augmented reality technology, the application addresses the critical challenges of misinterpretation and limited visualization. Stakeholders can now scan 2D GA drawings with their mobile devices, instantly revealing accurate 3D models. This advancement not only enhances visualization but also reduces the risk of errors resulting from misinterpretation, fostering better communication, and understanding among project team members.

ARchitect3D contributes to Goal 9 by introducing innovation and advanced technology to the construction industry, thereby revolutionizing infrastructure planning and design. Furthermore, the application aligns with Goal 11 by promoting sustainable urban development through improved visualization and reduced reliance on paper-based documentation. In addressing Goal 12, ARchitect3D minimizes paper usage, aligning with responsible consumption and production practices in construction. Additionally, by concurrently reducing paper usage and fostering efficiency, ARchitect3D aligns with Goal 13, thus contributing to climate action in construction practices. Notably, the application also exemplifies Goal 17 by fostering collaboration within the construction industry, particularly through cloud-based sharing for real-time information exchange.

In a nutshell, ARchitect3D stands as a transformative solution, not only overcoming construction challenges but also contributing significantly to global sustainability goals. The application's alignment with SDGs underscores its potential to drive positive change in the construction industry, promoting innovation, efficiency, and responsible practices.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

A literature review in a study is a comprehensive and critical examination of existing scholarly works, research studies, and literature pertinent to a specific topic or research question within a particular field of study. It is an integral component of any research endeavor, playing a pivotal role in shaping the conceptual framework and guiding the overall direction of the study (Denney and Tewksbury, 2013).

The primary purpose of a literature review is multifaceted. Firstly, it serves to provide a contextual backdrop for the research, placing it within the broader landscape of current knowledge. This contextualization helps to establish the relevance and significance of the study, ensuring that it contributes meaningfully to the existing body of literature.

Furthermore, a literature review aims to demonstrate the researcher's depth of understanding in the chosen field. By synthesizing and summarizing key theories, concepts, and empirical findings, the literature review showcases the researcher's familiarity with the subject matter. This not only reinforces the scholarly foundation of the study but also positions it as a thoughtful and informed contribution to the academic discourse.

A crucial function of the literature review is the identification of gaps and research questions. Through a systematic analysis of existing literature, researchers can discern areas where knowledge is lacking or where further exploration is warranted. These identified gaps then become the basis for formulating research questions, shaping the trajectory of the new study.

In addition, the literature review establishes the theoretical framework for the research. By integrating relevant theories and concepts from existing literature, it provides a conceptual scaffold upon which the study is built. This theoretical foundation not only informs the research methodology but also aids in the interpretation of results. Importantly, a well-constructed literature review avoids redundancy by ensuring that the proposed research builds upon existing knowledge rather than duplicating studies that have already been conducted. This requires a discerning analysis of previous research to pinpoint gaps that align with the goals of the new study.

In conclusion, a literature review is a dynamic and integral component of a research study. It serves as a compass, guiding the researcher through the existing scholarly landscape, identifying unexplored territories, and laying the groundwork for a meaningful and impactful contribution to the field.

2.2 CHALLENGES OF RELIANCE ON 2D TECHNICAL DRAWINGS

In the ever-evolving landscape of the construction industry, the reliance on traditional 2D technical drawings has long been a standard practice. However, as projects become more complex and demands for precision and efficiency increase, it becomes imperative to critically assess the limitations and challenges associated with an exclusive dependence on two-dimensional representations. This discourse aims to shed light on the drawbacks of overreliance on 2D technical drawings in the construction sector.

One of the primary challenges inherent in 2D technical drawings is the limited capacity to convey the spatial relationships within a three-dimensional environment accurately. Construction projects, by nature, exist in three-dimensional space, and relying solely on two-dimensional representations can lead to misunderstandings, miscalculations, and subsequent errors during the construction phase. Interpreting complex architectural and engineering designs from 2D drawings often requires a high level of expertise (Igarashi et al., 2007). Stakeholders involved in the construction process, including contractors and field personnel, may face challenges in visualizing the final built environment accurately. This lack of clarity can result in discrepancies between the intended design and the executed construction, leading to costly rework and delays.

While 2D technical drawings provide valuable information about plan views and elevations, they may lack crucial details regarding material specifications, construction sequencing, and other vital aspects of the project. Overreliance on these drawings may result in oversight and omission of critical information, potentially compromising the integrity of the construction process. Effective communication is paramount in the construction industry, involving various stakeholders such as architects, engineers, contractors, and subcontractors. Relying solely on 2D drawings may contribute to miscommunication due to the inherent abstraction of information. This can lead to discrepancies in understanding project requirements, ultimately impacting collaboration and coordination (Shih, 2001).

The transition from 2D drawings to the physical construction phase introduces the potential for errors, as interpreting and translating two-dimensional information into a three-dimensional reality is prone to mistakes. Errors in construction can result in costly rework, project delays, and disputes among project participants.

In a nutshell, 2D technical drawings remain a fundamental tool in the construction industry, their limitations must be acknowledged and addressed. Advancements in technology, such as Building Information Modeling (BIM) and Augmented Reality (AR), provide opportunities to overcome these challenges by offering a more comprehensive and integrated approach to project visualization and coordination.

2.3 ADDRESSING CONSTRUCTION SECTOR NEEDS THROUGH APPLIED AR INNOVATIONS

As Malaysia advances towards IR 4.0, the construction sector is presented with unprecedented opportunities for innovation and efficiency. Augmented Reality (AR), a cutting-edge technology, emerges as a transformative tool capable of addressing the specific needs of the construction industry.

Applied AR innovations enable real-time visualization of construction projects. Stakeholders can overlay digital models onto physical construction sites, providing an immersive experience that aligns with the principles of IR 4.0. This ensures that project participants have instant access to updated information, fostering better decision-making and collaboration. AR facilitates the creation of digital twins for construction projects, aligning with the core tenets of IR 4.0. By creating a digital replica of the physical environment, stakeholders can monitor and analyze construction processes in real time. This integration enhances efficiency, minimizes errors, and allows for predictive maintenance, thereby optimizing the entire project lifecycle (Côté et al., 2013).

IR 4.0 emphasizes interconnectedness, and AR plays a pivotal role in enhancing collaboration and communication among various stakeholders in the construction sector (Kamble et al., 2018). Through AR applications, team members can share information, visualize complex designs, and address issues collaboratively, leading to streamlined workflows and reduced project timelines. Applied AR solutions contribute to smart construction site management by providing real-time data on resource allocation, progress tracking, and safety compliance. This aligns with the smart manufacturing principles of IR 4.0, optimizing resource utilization and ensuring a safer and more efficient construction environment.

In the context of Malaysia's IR 4.0 initiatives, AR is instrumental in upskilling the workforce in the construction sector. Augmented Reality-based training modules provide immersive learning experiences, allowing workers to acquire new skills and stay abreast of technological advancements, thereby fostering a future-ready workforce.

The integration of applied Augmented Reality innovations in the Malaysian construction sector aligns seamlessly with the principles of IR 4.0. Real-time project visualization, digital twin integration, enhanced collaboration, smart site management, and skill development are pivotal aspects where AR technologies can bring about transformative change (Alaloul et al., 2022). As Malaysia embraces the era of IR 4.0, the adoption of these applied AR innovations promises to revolutionize the construction sector, fostering increased

2.4 SUSTAINABLE DEVELOPMENT GOALS (SDGs)

Figure 2.1: Sustainable Development Goals (Cernev & Fenner, 2020)

The Sustainable Development Goals (SDGs) for the year 2030 are a set of 17 global goals established by the United Nations to address diverse challenges and promote sustainable development across social, economic, and environmental dimensions (Cernev & Fenner, 2020).

These goals, adopted by all United Nations Member States in 2015, represent a shared commitment to work towards a better and more sustainable future. The SDGs encompass a wide range of objectives, including eradicating poverty, ensuring access to quality education, achieving gender equality, addressing climate change, and fostering peaceful and just societies.

The 17 SDGs cover various aspects of human well-being, environmental sustainability, and social justice. They acknowledge the interconnectedness of global issues and emphasize the need for collaborative efforts to address complex challenges. The goals are not isolated from one another; they are designed to be integrated and achieved collectively.

For instance, SDG 9 emphasizes the importance of building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. In the context of the SMCI project, this goal aligns with the need for sustainable infrastructure development and technological advancements in construction practices. The development of the ARchitect3D mobile application directly contributes to this goal by enhancing on-site 3D visualization, promoting efficient construction processes, and fostering innovation in project management.

Moreover, SDG 11 focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. The construction industry plays a pivotal role in achieving this goal by contributing to the development of sustainable urban infrastructure, affordable housing, and efficient transportation systems. The ARchitect3D mobile application supports this objective by providing advanced visualization tools that help in planning and developing resilient and sustainable urban projects.

In summary, the SDGs for 2030 provide a comprehensive framework for global cooperation, guiding efforts to build a more equitable, resilient, and sustainable world. The goals recognize the interdependence of various issues and stress the importance of collective action to create positive and lasting change on a global scale. By addressing specific challenges in the construction industry through innovative solutions like the ARchitect3D mobile application, this project contributes to the broader mission of achieving the SDGs.

2.5 INDUSTRY REVOLUTION 4.0

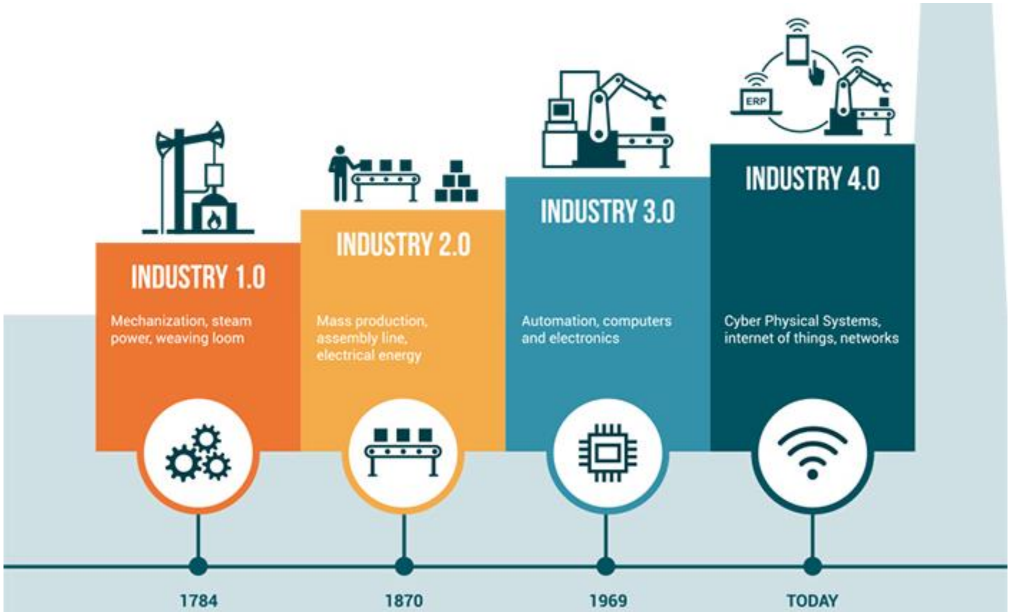


Figure 2.2: Innovation of Industry Revolution (Alaloul et al., 2018)

In Malaysia, the advent of Industry Revolution 4.0 (IR 4.0) has brought about transformative changes across various sectors, and the construction industry is no exception. This paradigm shift is characterized by the integration of digital technologies, automation, and data exchange, fundamentally altering the way construction processes are planned, executed, and managed. The Malaysian government, recognizing the significance of IR 4.0, has actively promoted its adoption to enhance the competitiveness and efficiency of industries. In the context of the construction sector, several key aspects are noteworthy (Alaloul et al., 2018).

IR 4.0 has prompted the digitalization of construction processes in Malaysia. This includes the use of Building Information Modeling (BIM) for collaborative project planning, design, and management. BIM facilitates real-time collaboration, reduces errors, and enhances overall project efficiency. The integration of IoT in construction is gaining traction. IoT devices such as sensors and monitoring equipment are utilized to collect real-time data on construction sites, enabling better decision-making, predictive maintenance, and improved safety measures. The industry is placing a significant emphasis on skill development to equip the workforce with the necessary competencies for IR 4.0. Training programs are designed to enhance digital literacy and proficiency in using advanced construction technologies.

The Malaysian government has rolled out initiatives to encourage the adoption of IR 4.0 technologies in the construction sector. This includes providing incentives, fostering collaboration, and creating a conducive regulatory environment. IR 4.0 technologies contribute to enhanced efficiency in construction processes, reducing project timelines and costs. Moreover, the integration of sustainable practices, supported by digital technologies, aligns with global environmental goals.

In line with these advancements, the development of the ARchitect3D mobile application represents a significant stride in adopting IR 4.0 technologies in the Malaysian construction industry. This application leverages augmented reality to enhance on-site 3D visualization, addressing the need for more precise and efficient project management. By incorporating features such as real-time data integration and interactive 3D models, ARchitect3D supports the industry's move towards smarter construction practices. This innovative solution aligns with the objectives of IR 4.0 by promoting digital collaboration, improving project accuracy, and fostering a safer and more efficient construction environment.

In conclusion, the integration of IR 4.0 in the Malaysian construction industry signifies a shift towards more advanced, efficient, and sustainable practices. As digital technologies continue to evolve, the construction sector is poised to benefit from increased productivity, improved safety measures, and a more competitive stance in the global market. The ARchitect3D mobile application exemplifies how embracing IR 4.0 technologies can drive innovation and excellence in construction, ultimately contributing to the sector's long-term success.

2.6 AUGMENTED REALITY

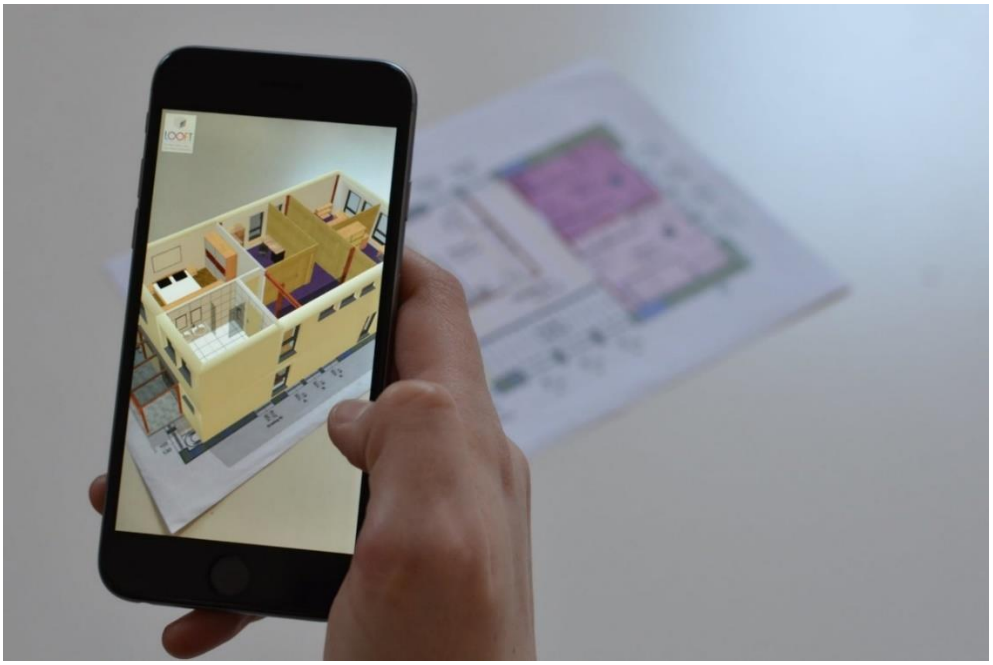


Figure 2.3: Augmented Reality

Augmented Reality (AR) is a technology that enriches the real-world environment by overlaying computer-generated information onto it. It offers a dynamic and interactive experience, seamlessly integrating digital elements with the user's view of the physical world. Unlike virtual reality, AR enhances reality rather than creating a completely immersive digital environment.

AR applications are diverse and span across multiple industries. In healthcare, it aids in medical training and surgeries, while in education, it enhances learning experiences. Retail utilizes AR for virtual try-ons, and the construction industry benefits from AR for project visualization. Gaming experiences are elevated by integrating digital elements into the real world (Chen and Xue, 2022).

Devices for AR experiences range from smartphones and tablets, where AR-enabled apps are common, to dedicated AR headsets like Microsoft HoloLens or Google Glass, providing a more immersive encounter. AR can be marker-based, where specific markers trigger digital content, or markerless, relying on device sensors to interact with the environment without markers.

One of AR's distinguishing features is real-time interaction, allowing digital elements to respond to changes in the user's surroundings. Navigation and exploration apps leverage AR to provide real-time information about the user's environment, offering directional guidance through overlays.

In the context of the development of the ARchitect3D mobile application leverages AR technology to enhance on-site 3D visualization. This application overlays digital information onto the physical construction site, allowing for real-time project visualization, precise planning, and better decision-making. By integrating AR, the ARchitect3D application not only addresses the current visualization challenges but also aligns with the broader objectives of Industry Revolution 4.0, promoting innovation and efficiency in the construction industry.

In summary, augmented reality transforms how we perceive and interact with the world by seamlessly blending digital information with the real environment. Its versatile applications across industries and ongoing technological advancements contribute to its growing significance in shaping interactive and immersive experiences. The ARchitect3D mobile application exemplifies the potential of AR in revolutionizing construction practices, making project visualization more intuitive and effective.

2.7 AUTODESK REVIT

Figure 2.4: Autodesk Revit

Autodesk Revit is a Building Information Modeling (BIM) software developed by Autodesk, a leading software company in the field of design, engineering, and construction. Released in 2000, Revit has become a widely used and influential tool in the architecture, engineering, and construction (AEC) industries. Unlike traditional Computer-Aided Design (CAD) software, Revit is specifically designed for BIM, enabling users to create and manage intelligent 3D models of buildings and infrastructure (Ferrandiz, et al., 2018).

In the development of ARchitect3D, Revit plays a crucial role in creating the 3D models that form the basis of the application's augmented reality experiences. By leveraging Revit's parametric design capabilities, users can generate intelligent components with dynamic properties, ensuring consistency and accuracy throughout the model. The software's collaboration features facilitate coordination among architects, engineers, and other stakeholders, fostering a seamless exchange of project data.

In summary, Autodesk Revit serves as a powerful BIM tool that streamlines the design and construction process, promoting collaboration, accuracy, and efficiency in the creation of complex building projects, including the development of the ARchitect3D mobile application.

2.8 UNITY 3D

Figure 2.5: Unity 3D

Unity 3D is a versatile and widely used game development engine that has expanded beyond the gaming industry to support the creation of various applications, including interactive simulations, virtual reality (VR) experiences, augmented reality (AR) applications, and more.

Unity 3D is commonly used for creating AR and VR applications (Jerald et al., 2014). The engine supports AR Foundation for augmented reality development and offers integration with VR devices for immersive virtual reality experiences. Unity 3D, renowned for its versatility and widespread adoption in the game development industry, serves as the foundational engine for creating the ARchitect3D mobile application. Unity 3D's cross-platform development capabilities are particularly advantageous for ARchitect3D, allowing developers to create applications that seamlessly run on mobile devices (Android). Leveraging Unity's robust features for realistic graphics, 3D environments, and interactive elements, ARchitect3D delivers an immersive and engaging user experience.

Furthermore, Unity's support for 3D modeling and animation enables the integration of dynamic visual elements, enhancing the application's visual appeal and interactivity. Unity's integration with AR Foundation for augmented reality development and its support for VR devices further solidify its suitability for creating AR and VR applications like ARchitect3D.

2.9 FIREBASE

Figure 2.6: Firebase

Firebase is a comprehensive mobile and web application development platform provided by Google. It offers a wide range of tools and services that simplify and accelerate the development process. Firebase is known for its real-time database, authentication services, cloud functions, hosting, and more (Khawas and Shah, 2018).

Firebase provides a NoSQL cloud database that supports real-time data synchronization. This is particularly useful for applications where multiple users need instant access to the same data. Firebase Authentication simplifies the process of implementing user authentication, supporting methods such as email/password, social media logins (Google, Facebook, Twitter), and others.

Firebase provides a set of tools for managing user authentication and access control, ensuring secure access to resources based on user roles and permissions. Firebase offers cloud storage for securely uploading and serving user-generated content. Firebase Cloud Messaging (FCM) allows developers to send notifications and messages to users across various platforms, including iOS, Android, and web. Moreover, Firebase plays a crucial role in storing and managing user data within the ARchitect3D application.

In conclusion, Firebase offers a unified and integrated platform that streamlines various aspects of app development, from backend infrastructure to frontend features. Its ease of use, scalability, and the ability to integrate with other Google Cloud services make it a popular choice among developers for building dynamic applications.

2.10 VISUAL STUDIO

Figure 2.7: Visual Studios

Visual Studio is an integrated development environment (IDE) created by Microsoft. It provides developers with a comprehensive set of tools for designing, coding, testing, and debugging software. Visual Studio supports a wide range of programming languages and frameworks, making it a versatile choice for various types of development projects.

Visual Studio offers a powerful and feature-rich IDE that provides a unified interface for software development. It includes code editors, debuggers, design surfaces, and various tools for building applications. Visual Studio supports multiple programming languages, including C#, Visual Basic, C++, F#, Python, and more. Developers can choose the language that best suits their project requirements (Cook et al., 2007). For the development of the ARchitect3D, C# was used as the primary programming language.

Visual Studio provides advanced code editing features, including syntax highlighting, code completion, and IntelliSense, which offers context-aware code suggestions to improve coding efficiency. Visual Studio supports mobile application development for iOS, Android, and Windows platforms using Xamarin. It also provides tools for cloud development, including integration with Azure services.

2.11 GOOGLE DRIVE

Figure 2.8: Google Drive

Google Drive is a cloud-based file storage and synchronization service provided by Google. It allows users to store files in the cloud, access them from various devices, and collaborate on documents in real-time (Gallaway, 2013).

Google Drive provides users with cloud storage space where they can store documents, images, videos, and other files. These files can be accessed and synchronized across multiple devices, including computers, smartphones, and tablets. Users can access their Google Drive through a web-based interface, allowing them to manage and organize their files using a web browser. The interface is user-friendly and includes features for file organization and sharing. Google Drive employs security measures to protect user data, including encryption during file transfer and storage.

In the context of the ARchitect3D mobile application, Google Drive is utilized as the cloud storage solution for all related drawings and project files. This integration ensures that all architectural drawings and related documents are easily accessible and can be synchronized across different devices, facilitating on-site and off-site access for project stakeholders.

In summary, Google Drive is a versatile and widely used cloud storage service that simplifies file management, sharing, and collaboration. Its integration with the ARchitect3D application enhances the efficiency of accessing and managing architectural drawings, making it a valuable tool for individuals and businesses involved in construction and architectural projects.

2.12 VUFORIA

Figure 2.9: Vuforia

Vuforia is an augmented reality (AR) software development kit (SDK) that allows developers to create AR applications for a variety of platforms. It is developed by PTC and is widely used for building interactive and immersive AR experiences.

Vuforia specializes in image recognition technology, enabling AR applications to recognize and track images or objects in the real world. This feature is essential for creating AR experiences that respond to specific visual cues. Vuforia supports marker-based AR, where predefined images or markers act as triggers for digital content. When the camera detects these markers, associated digital elements such as 3D models, videos, or interactive information are superimposed in real-time (Xiao and Lifeng et al.,2014).

Vuforia also supports markerless AR, allowing developers to create applications that recognize and track objects or environments without the need for predefined markers. This feature enables AR applications to interact with physical objects in the real world, enhancing the level of realism in the AR experience. In the development of ARchitect3D, Vuforia is utilized to generate target images, subsequently exported into Unity for integration.

In conclusion, Vuforia is widely used in various industries, including gaming, education, marketing, and industrial applications, to create immersive and interactive AR experiences. Its robust features and ease of integration make it a popular choice for developers working on AR projects.

2.13 ANGULAR

Figure 2.10: Angular

To streamline the management of ARchitect3D users, the researcher employed Angular, a powerful and versatile front-end framework, to develop an administrative website. This website allows administrators to efficiently approve, reject, or block users of the ARchitect3D mobile application.

The decision to use Angular was influenced by its strong community support, extensive documentation, and compatibility with modern web development practices. Angular's two-way data binding ensures that any changes made by administrators are immediately reflected in the system, providing real-time updates and maintaining the integrity of the user management process.

Moreover, Angular's dependency injection and component-based structure enhance code maintainability and scalability, allowing for future enhancements and integrations. The website also incorporates security features to protect sensitive user information and ensure that only authorized personnel can perform administrative actions.

In conclusion, the use of Angular to develop the administrative website for managing ARchitect3D users underscores the researcher's commitment to leveraging advanced technologies to support efficient and secure user management. This website not only facilitates the smooth operation of the ARchitect3D application but also aligns with best practices in web development and administrative functionality.

2.14 BIMx

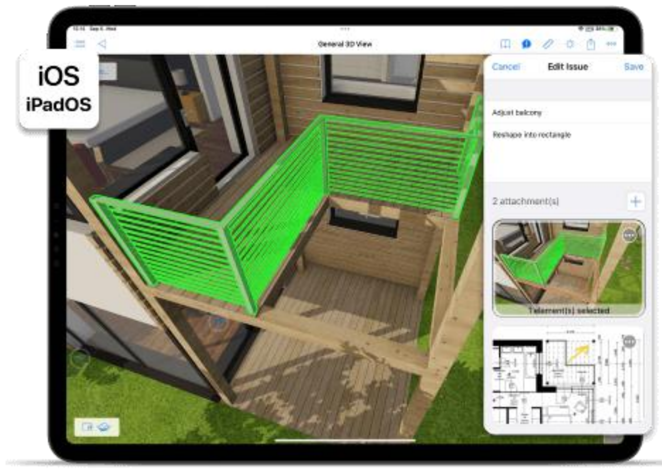


Figure 2.11: BIMx APPLICATION

BIMx, developed by GRAPHISOFT, is a pivotal tool in the construction industry due to its advanced 3D visualization capabilities integrated with Building Information Modeling (BIM). This application allows architects, engineers, and stakeholders to navigate complex architectural models seamlessly. By merging interactive 3D models with detailed 2D drawings such as floor plans and sections, BIMx enhances spatial understanding and construction details. This comprehensive visualization not only improves design comprehension but also facilitates effective communication and decision-making among project teams. With features like augmented reality (AR) integration for on-site visualization, BIMx continues to set benchmarks in enhancing project efficiency and collaboration, ensuring projects are executed with precision and adherence to design intent (Al Husaini, 2021).

Overall, BIMx serves as a versatile tool that not only enhances 3D visualization capabilities but also streamlines communication and collaboration within construction projects. Its integration with BIM workflows empowers stakeholders to achieve greater project clarity and efficiency, ultimately contributing to the successful delivery of complex construction ventures.

2.15 MAGICPLAN

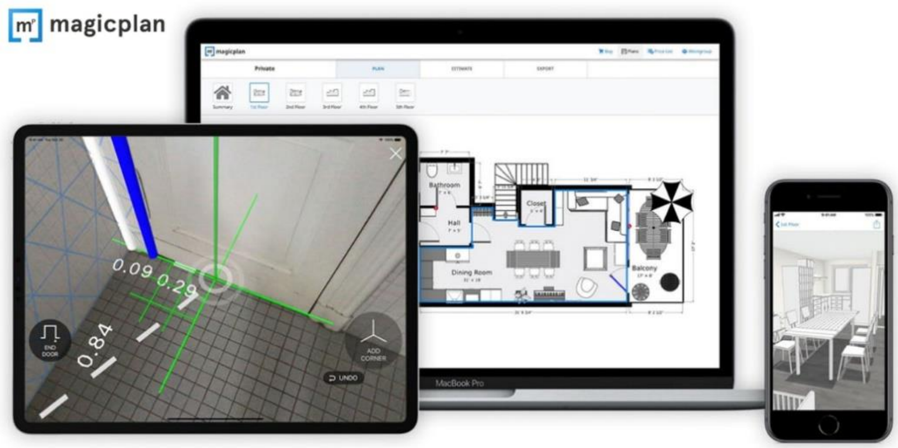


Figure 2.12: Magicplan

MagicPlan is a versatile mobile application that holds significant utility in the construction industry for creating accurate floor plans and visualizing spaces in 3D. Available on both iOS and Android platforms, MagicPlan utilizes the device's camera to scan rooms and generate precise 2D floor plans automatically. This functionality proves invaluable for construction professionals, including architects, engineers, and contractors, who require detailed floor plans as foundational documents for project planning and execution.

Beyond its capability to generate 2D floor plans, MagicPlan enhances its utility with augmented reality (AR) features. Users can view their floor plans in 3D directly on their mobile devices, overlaying digital representations onto real-world spaces. This AR functionality aids in visualizing how designs fit within existing environments, facilitating better decision-making during the design phase and enabling stakeholders to communicate effectively about spatial layouts and construction requirements. By streamlining the process of creating and visualizing floor plans, MagicPlan contributes to improved efficiency, accuracy, and collaboration in construction projects, ultimately leading to smoother project execution and enhanced client satisfaction (Aarlien, 2021).

2.16 PLANNER 5D

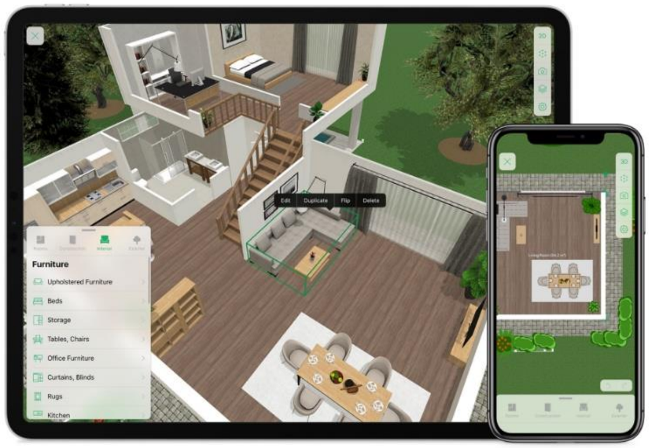


Figure 2.13: Planner 5D

Planner 5D is a robust mobile application that offers comprehensive tools for designing and visualizing interior spaces, making it a valuable asset in the construction industry. Available on both iOS and Android platforms, Planner 5D allows users to create detailed 2D floor plans and then seamlessly transition them into immersive 3D models. This capability is particularly beneficial for architects, interior designers, and construction professionals who need to conceptualize and communicate spatial layouts effectively (Dreimane, and Zālīte-Supe, 2022).

The app's augmented reality (AR) mode further enhances its utility by enabling users to view their designs in real-time within their physical environments. By overlaying digital representations onto real-world spaces through a smartphone or tablet camera, Planner 5D facilitates on-site visualization and decision-making. This feature is instrumental during client presentations, allowing stakeholders to experience proposed designs firsthand and make informed choices about materials, finishes, and spatial configurations. Overall, Planner 5D empowers construction professionals to streamline design processes, enhance client engagement, and achieve more efficient project outcomes through its intuitive interface and powerful visualization capabilities.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The methodology section of a research study outlines the systematic plan of action employed to conduct the investigation, collect data, and analyze findings. It serves as a roadmap that details the research design, participants, instruments or tools used, and procedures undertaken to address the research questions or objectives. A robust methodology is essential for ensuring the reliability, validity, and replicability of the study (Thomas, 2021).

In this study, the chosen research design forms the backbone of the methodology, providing a blueprint for the overall approach to addressing the specific issues identified at the SMCI project site. The study aims to identify client needs and overcome problems by leveraging innovative approaches. The participants of this study, consisting of 30 on-site respondents, provided insights into the challenges faced, particularly the lack of adequate 3D visualization tools. The data collected through a quantitative survey highlighted these issues, prompting the researcher to develop the ARchitect3D mobile application using Unity 3D software. This application is designed to enhance on-site 3D visualization, thereby addressing the identified needs.

The methodology also includes evaluating the effectiveness of the ARchitect3D mobile application. This evaluation is conducted through another survey with data analyzed using SPSS software to measure the application's impact on resolving site issues.

3.2 RESEARCH DESIGN

Research design refers to the application of innovative approaches and methodologies in the process of conducting research. It involves utilizing creative and cutting-edge techniques to address research questions, explore new areas of inquiry, and generate novel insights. Table 3.1 shows the research design for this study.

Table 3.1: Research Design

OBJECTIVE	METHOD	INSTRUMENT	OUTCOME
To identify the client needs to overcome the problems on SMCI project site.	Survey	Quantitative – Questionnaire through Google Form	Identifying the problems encountered on the SMCI project site.
To develop ‘ARchitect3D’ mobile application using Unity software.	Develop	Unity 3D software	Develop a user friendly Architect3D mobile application using Unity 3D software.
To evaluate the effectiveness of ‘ARchitect3D’ mobile application.	Survey	Quantitative – Questionnaire through Google Form	Analyze the data using SPSS software to obtain the highest mean and standard deviation to determine the effectiveness of the Architec3D mobile application.

3.3 DEVELOPMENT OF RESEARCH

The methods and approaches employed in designing a research study are influenced by the researcher's perspective on the nature of knowledge and reality, often shaped by their disciplinary background (Kumari et al., 2023). Figure 3.1 below illustrates the research strategy adopted for this study with phase 1, 2 and 3.

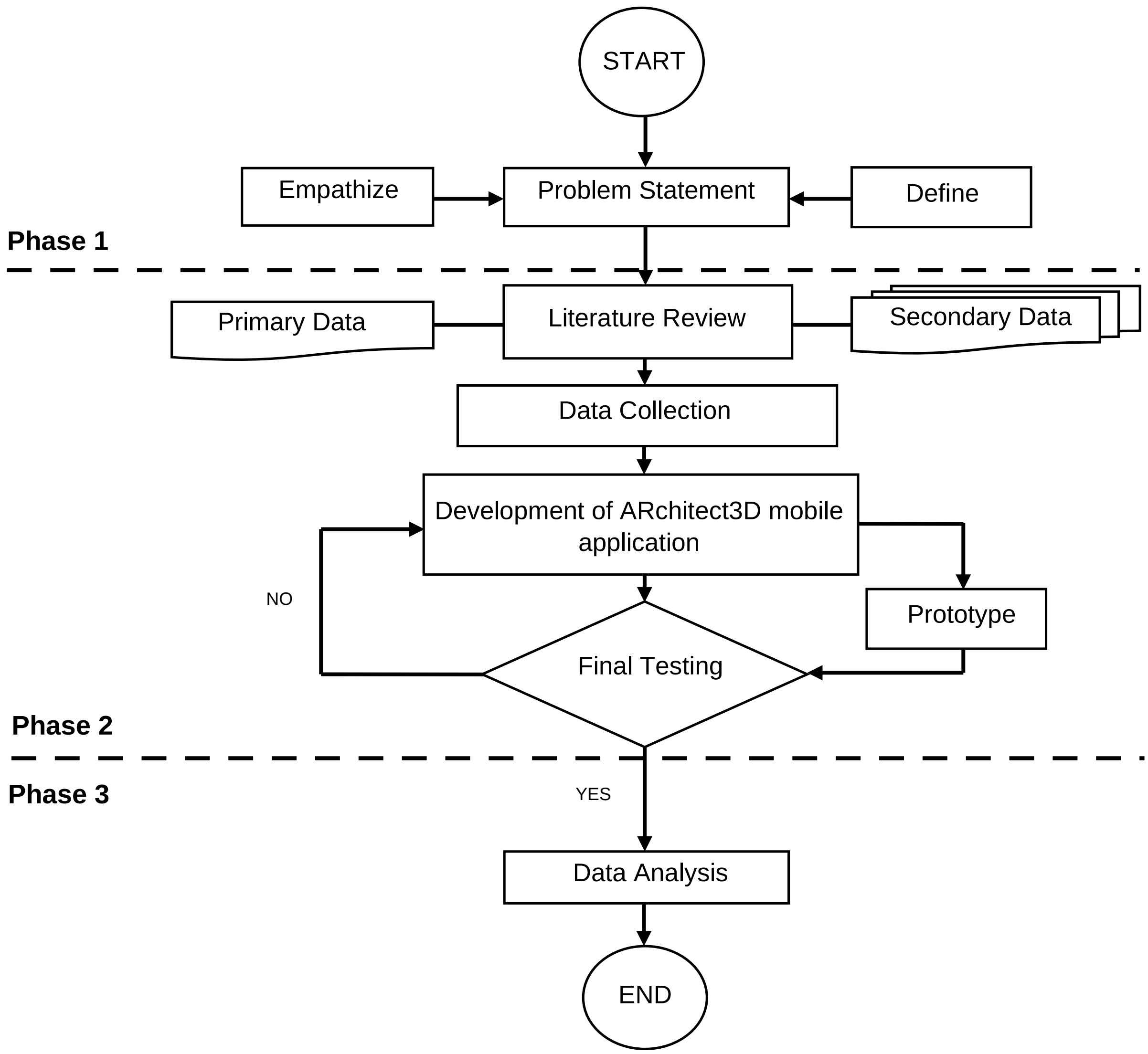


Figure 3.1: Research Flowchart

3.4 PROBLEM ENCOUNTERED IN SMCI PROJECT SITE

The researcher conducted a quantitative survey through a questionnaire with 30 on-site respondents including project engineers, architects, site coordinators, and site supervisors, who are all directly involved in the SMCI project to achieve objective 1; identifying client needs to overcome problems on the SMCI project site. The questionnaire, as shown in Appendix B, consisted of Section A for demographics and Section B to identify client needs to overcome problems on the SMCI project site. The survey aimed to gather comprehensive insights into the challenges faced on-site and the specific needs of clients to enhance project efficiency and effectiveness.

3.5 DEVELOPMENT OF ARCHITECT3D MOBILE APPLICATION

The development process of ARchitect3D using Unity software involved a systematic approach comprising several key phases and components

3.5.1 Revit

Firstly, a 3D model is required to create the visualization. The 3D model is constructed using Autodesk Revit with three different models: architectural, mechanical and electrical (M&E), and a combination of architectural and M&E as shown in Figure 3.2 and 3.3. These models are then converted into .fbx files to be exported into Unity software.

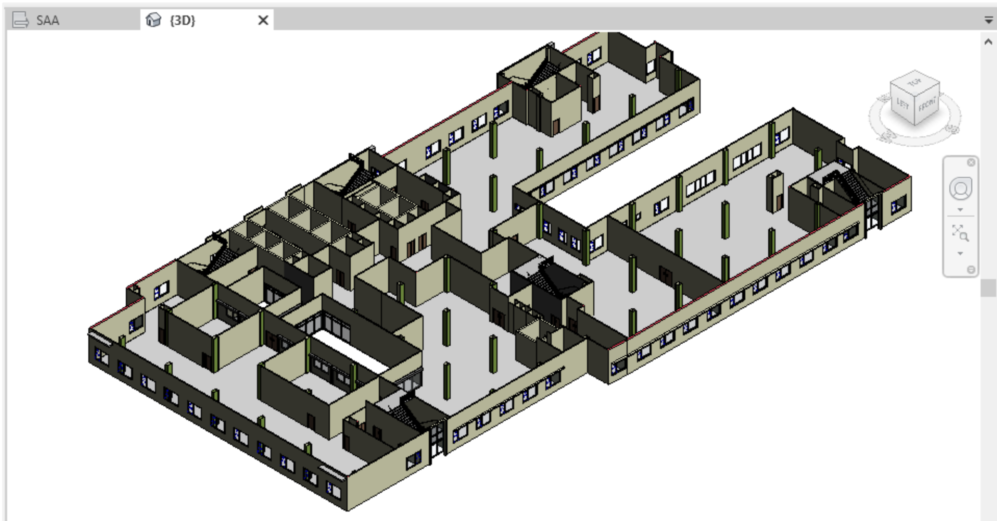


Figure 3.2: Architectural Model

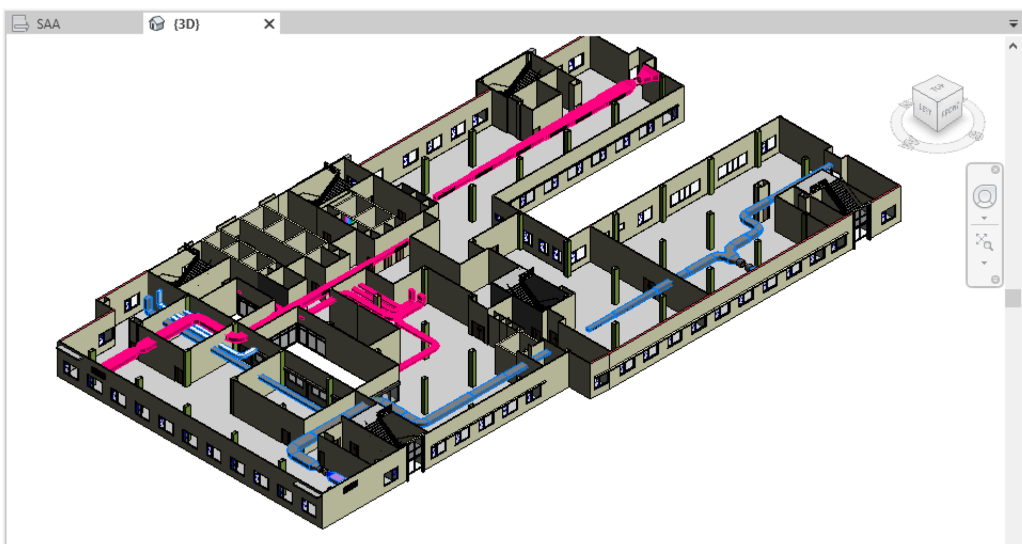


Figure 3.3: Architectural and M&E Model

3.5.2 Vuforia

Secondly, using Vuforia, the target image for the application is created and registered to obtain the project license key. In this case, the researcher created the Level 7 floor plan as the target image. As shown in Figure 3.4, the target image must achieve a minimum of 4 stars after registration in Vuforia to ensure the camera can detect it as a target later. The license key obtained from creating the target image is then exported into Unity as illustrated in Figure 3.5.

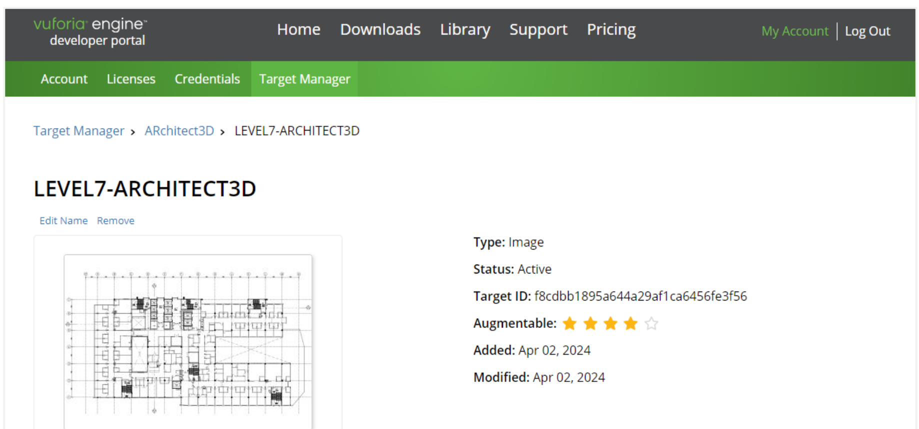


Figure 3.4: Target Image Rating

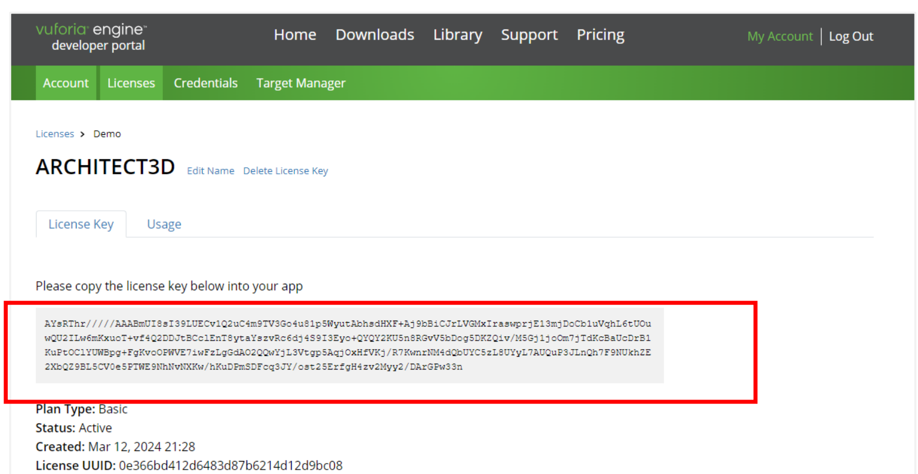


Figure 3.5: Vuforia License Key

3.5.3 Unity

After importing the license key into Unity, the image target will automatically appear. The researcher then imports the created 3D models into Unity and places them accordingly on the target image as shown in Figure 3.6.

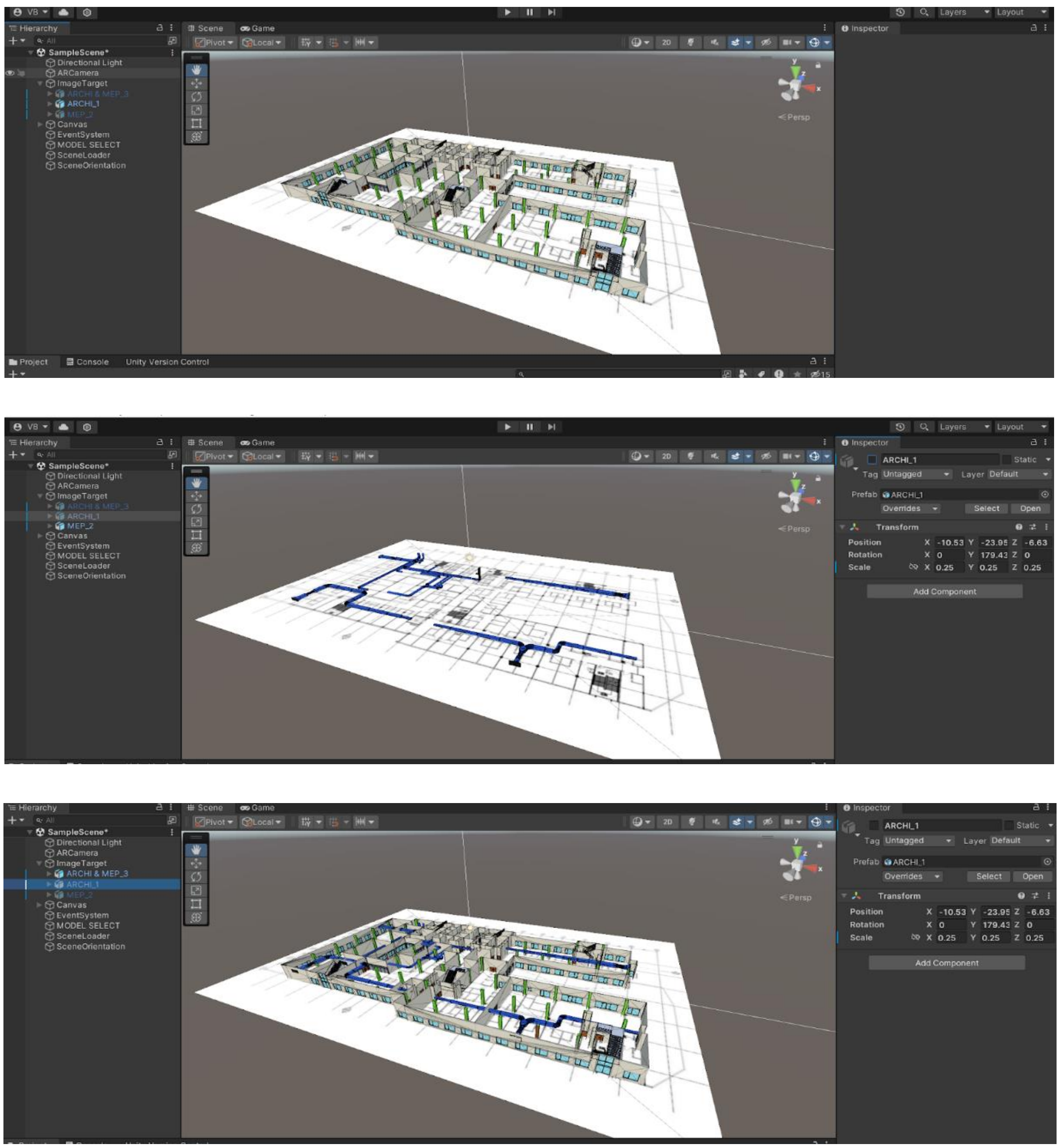


Figure 3.6: 3D Model Attached on the Target Image

The next step involves creating the ARchitect3D interface and buttons, utilizing Unity and Visual Studio. Visual Studio is essential for assigning functionalities to the buttons through coding, and the researcher used C# language as shown in Figure 3.10, to create those interfaces displayed in Figure 3.7 to 3.9. Initially, the ARchitect3D layout is designed, ensuring that the buttons are appropriately placed according to the screen size. This careful placement is crucial for maintaining a professional and elegant appearance for the application.

Figure 3.7: Login Interface

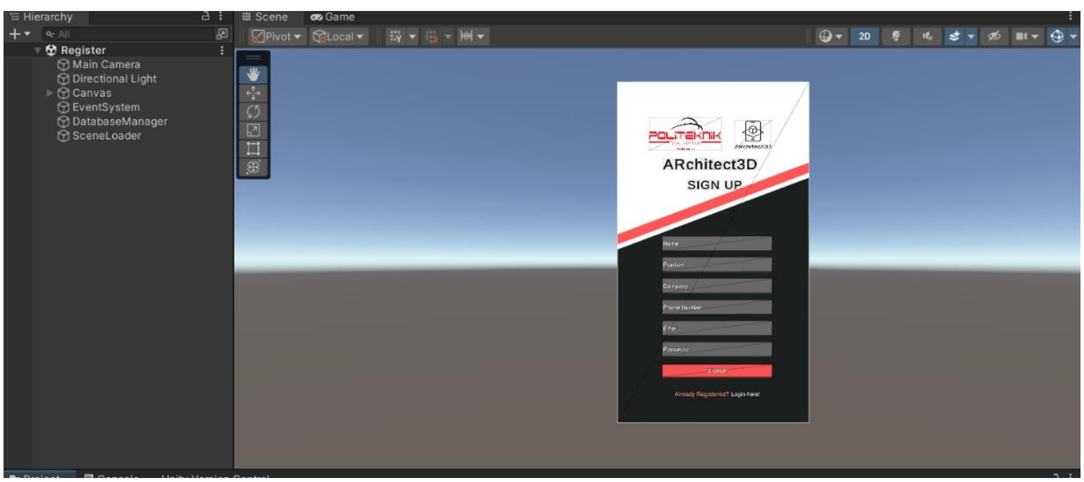


Figure 3.8: Sign Up Interface

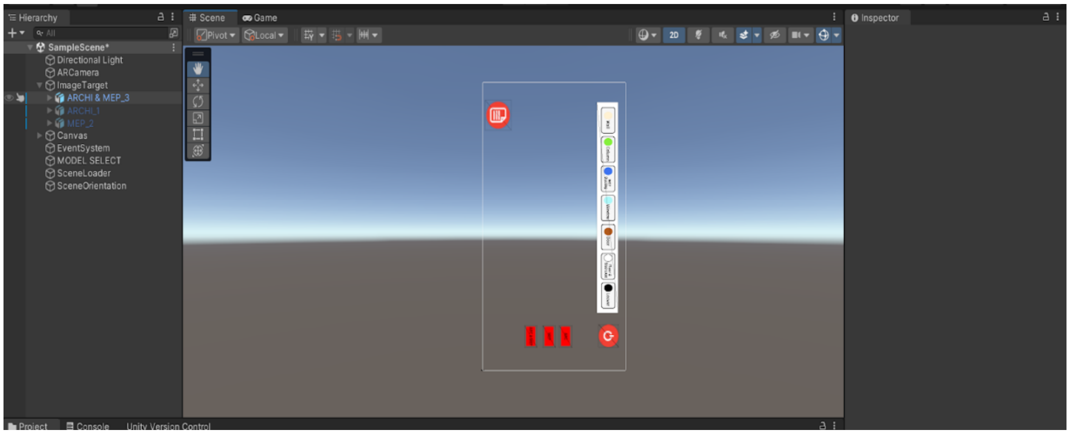


Figure 3.9: Augmented Reality Interface

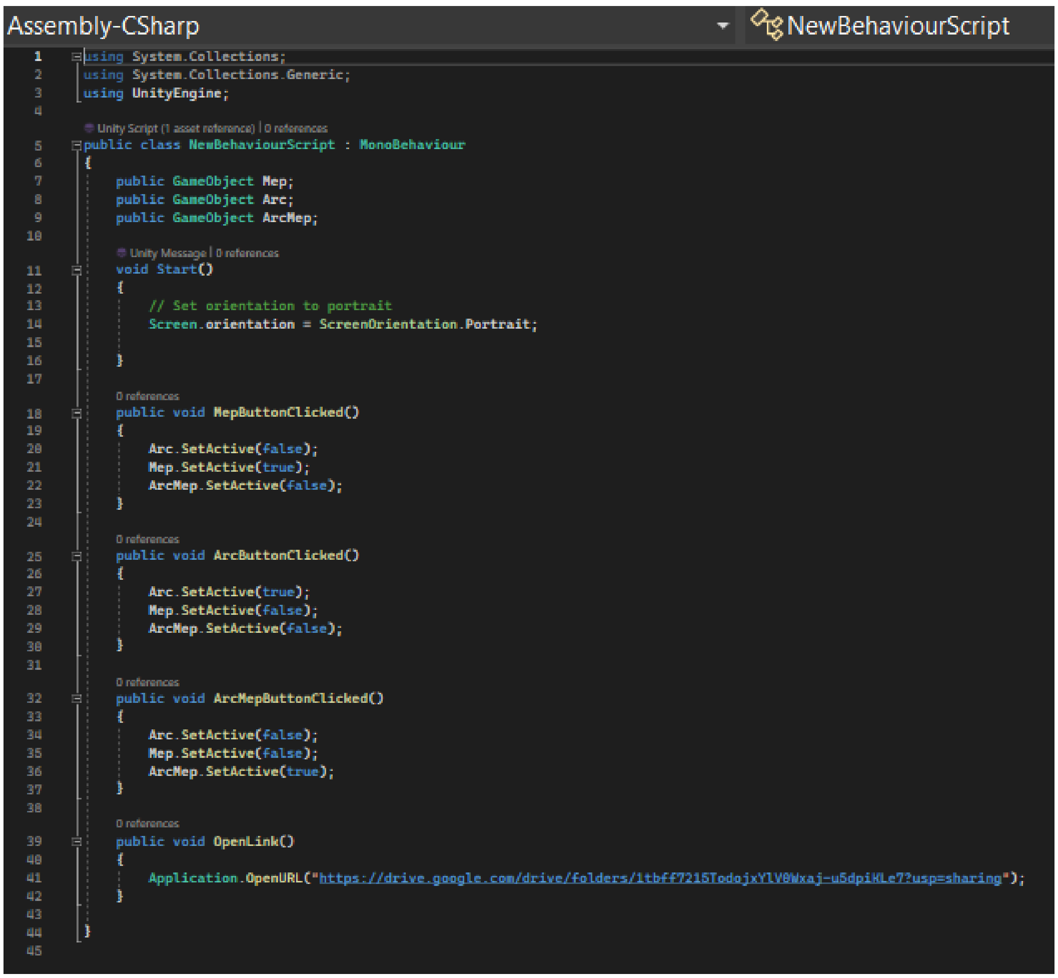


Figure 3.10: Part of Coding in Visual Studios

3.5.4 Firebase

Firebase is used instead of Unity to avoid local storage usage during registration and login, reducing storage requirements and increasing reliability. Additionally, the Firebase Realtime Database is employed to store user data during registration and to handle user errors during the registration process, as shown in Figures 3.11 and 3.12. Subsequently, Figure 3.13 displays the assigned Firebase database is integrated into Unity using Visual Studio through coding.

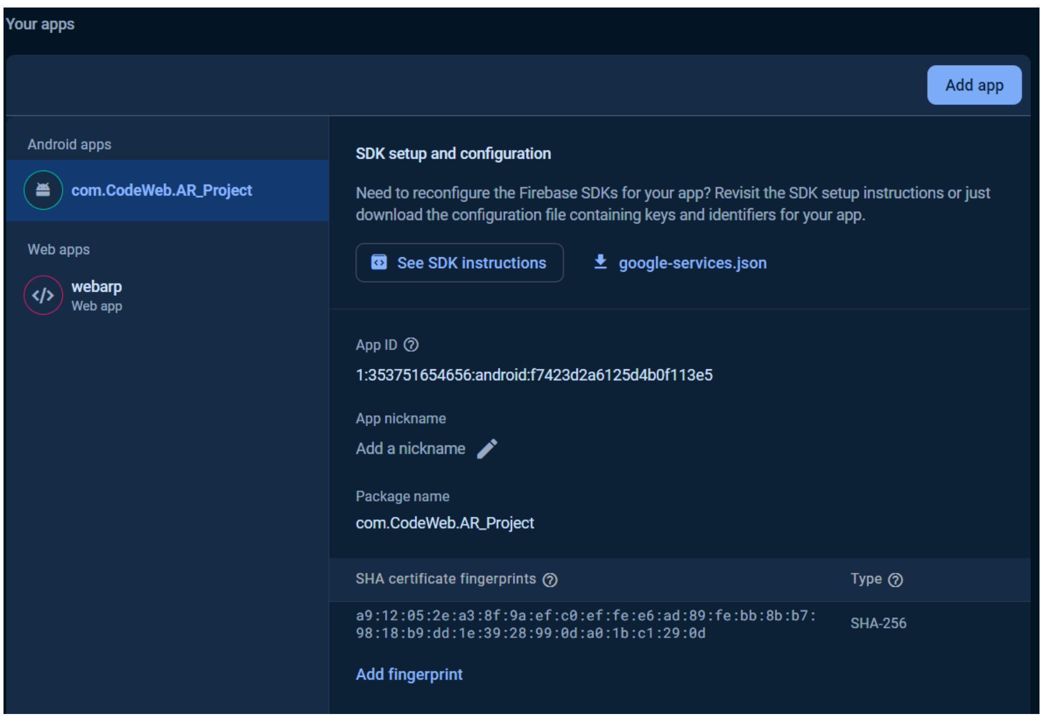


Figure 3.11: Firebase Setup

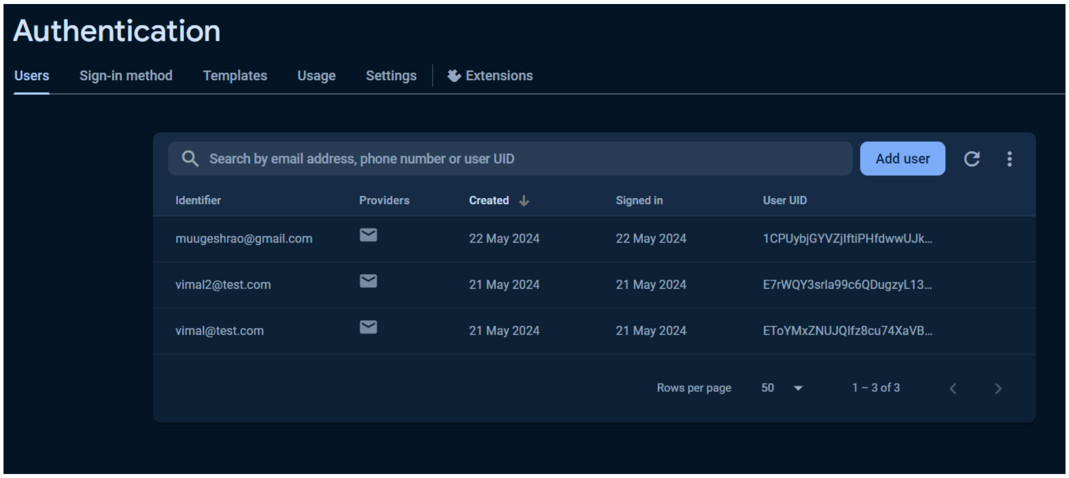


Figure 3.12: Firebase Authentication

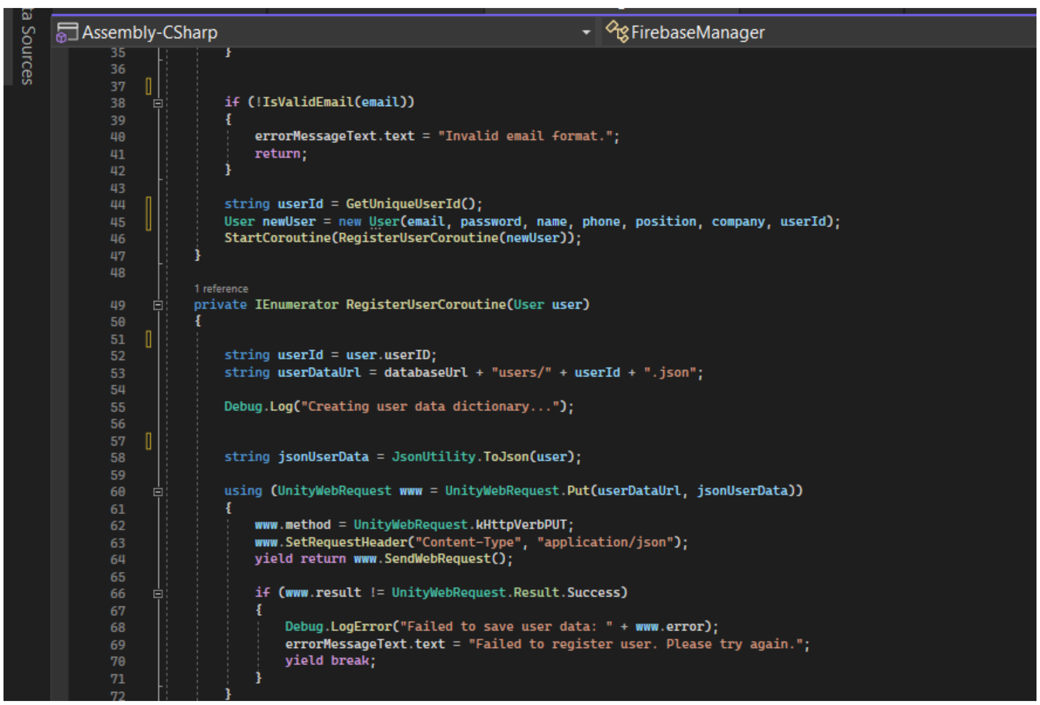


Figure 3.13: Part of Visual Studio Coding

3.5.5 Angular

The researcher has opted to develop a website to facilitate the approval, rejection, and blocking of users from logging into the application, providing an added layer of security and confidentiality for the private drawings. The website shown in Figure 3.14, built using Angular, serves as an exclusive platform for administrators to review newly registered user data before verifying and approving their access to the application. Upon approval, administrators will notify verified users to proceed with logging in, as shown in Figure 3.15. For users whom the administrator cannot verify, they will be rejected through the website, preventing access to the application. Additionally, the website includes a feature to block approved users at any time, ensuring stringent control over access privileges, as illustrated in Figure 3.16.

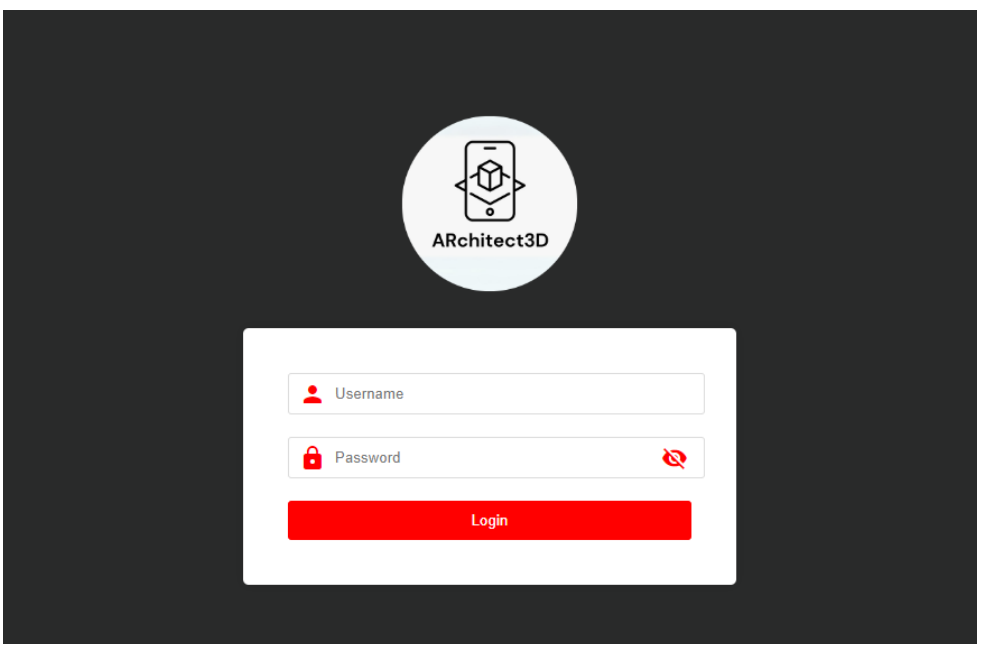


Figure 3.14: Admin Login Interface

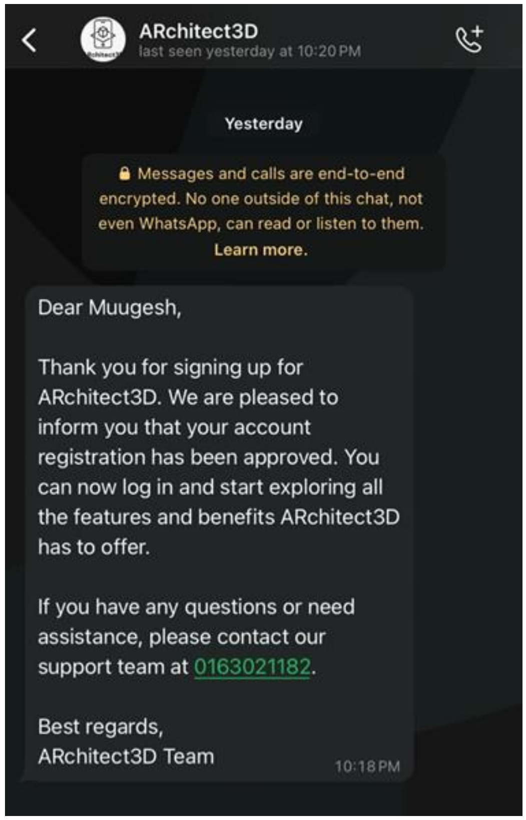


Figure 3.15: User Notification Upon Approval

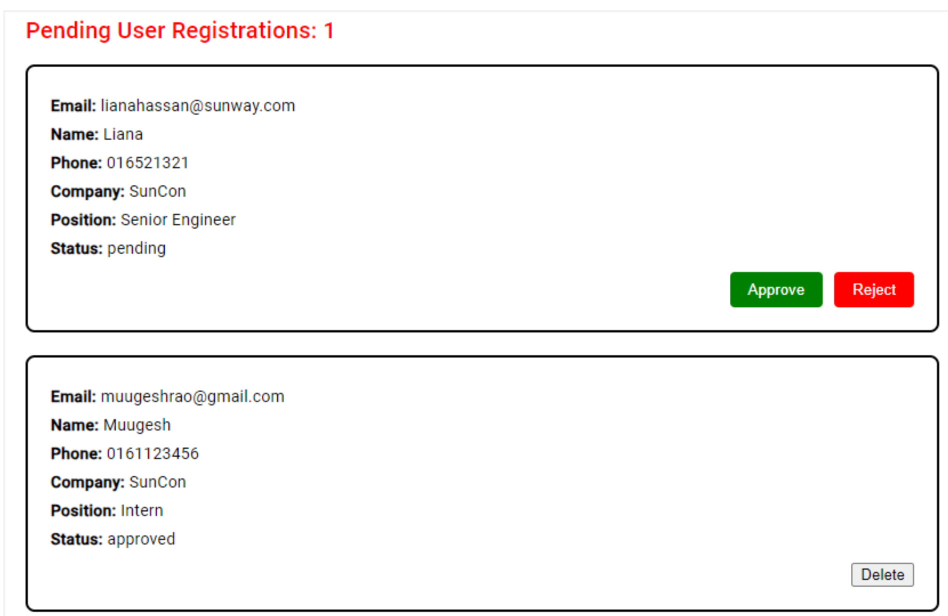


Figure 3.16: User Review Interface

3.5.6 Build and Run

After successfully creating all the interfaces and button functionalities, the researcher needs to convert the files into .apk format to enable installation on devices, as shown in Figure 3.17 and 3.18. Once converted, users can install and run the application, allowing them to interact with the augmented reality features and access the functionalities provided.

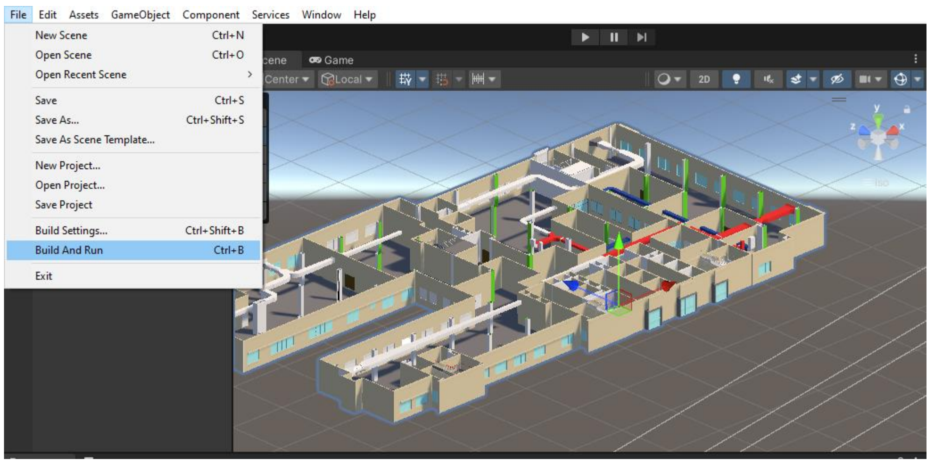


Figure 3.17: Build and Run

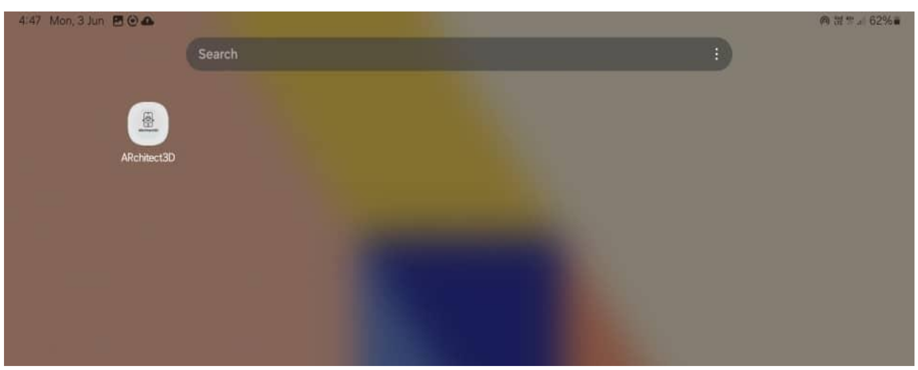


Figure 3.18: ARchitect3D Icon After Installing in Device

3.5.7 ARchitect3D Interface

Figure 3.19 to 3.21 show the user interface of ARchitect3D, its functionality, and the steps to use the mobile application.

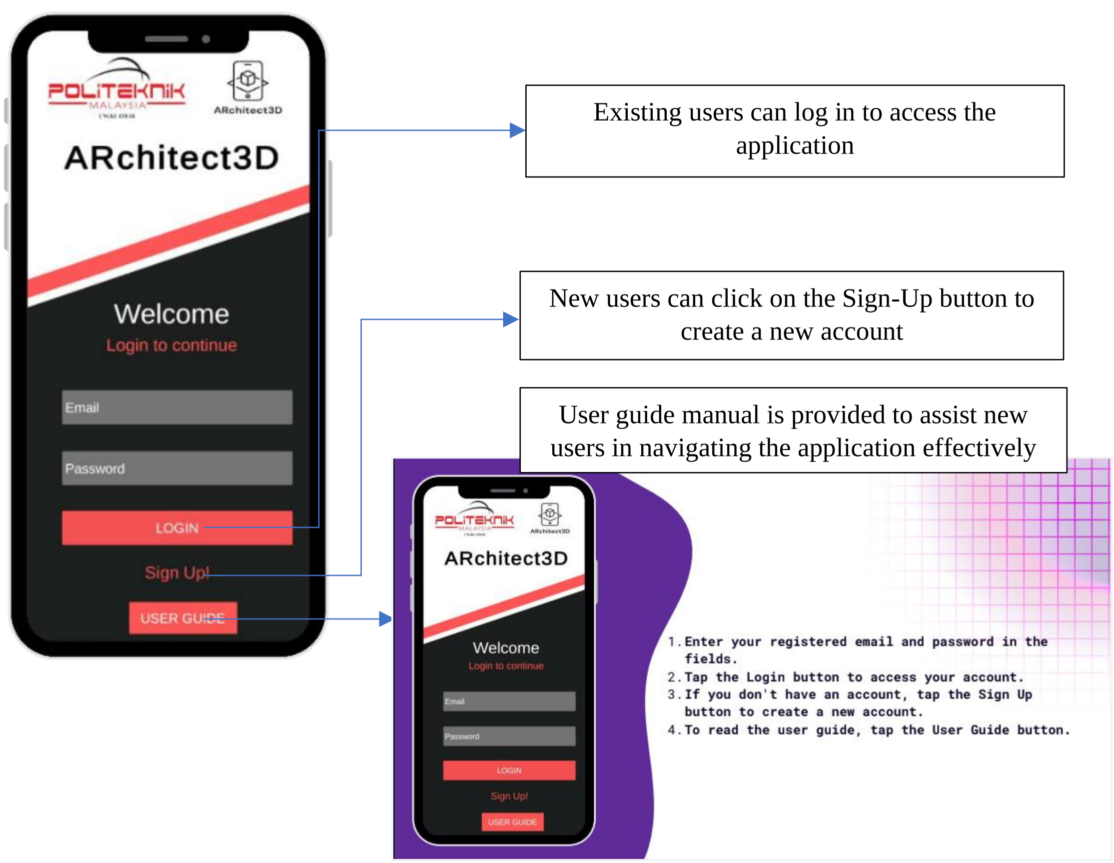


Figure 3.19: Log-In Interface

To log in, users should enter their registered email and password in the respective fields and then tap the Login button to access their account. If users do not have an account, they can tap the Sign-Up button to create a new one. Additionally, users who wish to read the user guide can do so by tapping the User Guide button.

To create an account, enter your details in the respective fields and create a password with more than six characters. Then, tap the Sign-Up button to register your account. You will be able to log in once you receive the activation notification.

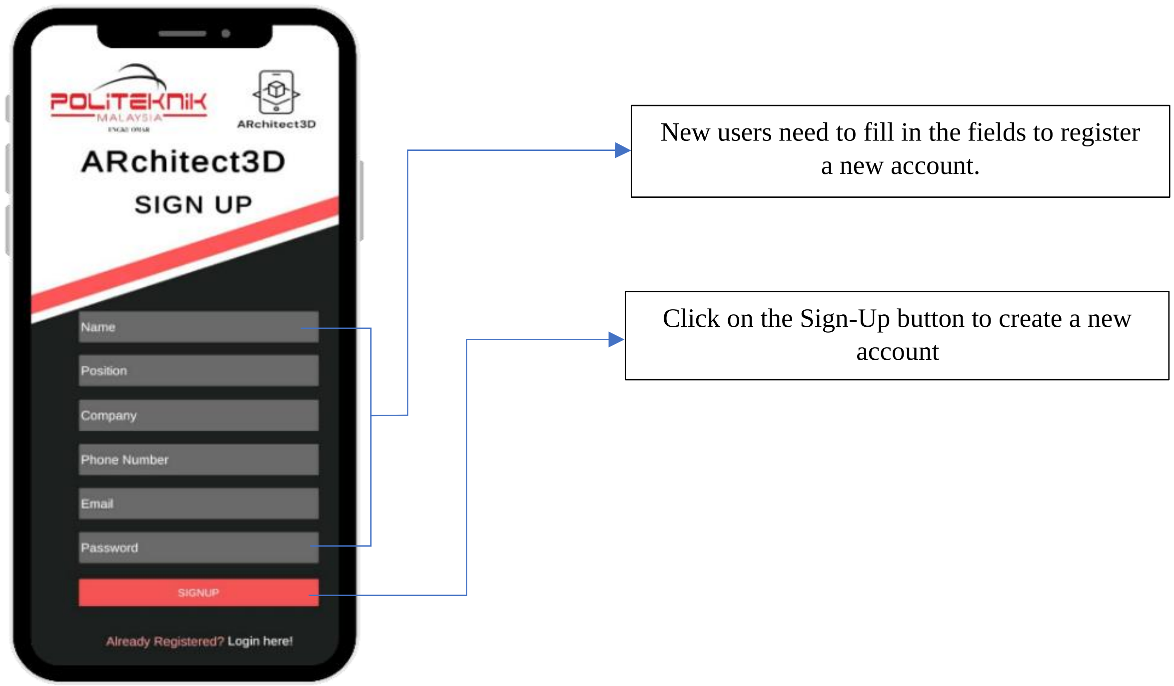


Figure 3.20: Sign-Up Interface

After logging in, scan the 2D drawing with your device camera, and the selected 3D model will appear. User can then tap the ARC, MEP, or ARC&MEP button to view the respective 3D model as shown in Figure 3.21. A color-coded legend is available above the interface to indicate the elements and their respective colors. To access related drawings, tap the documents icon button. Finally, tap the logout icon to log out of the application.

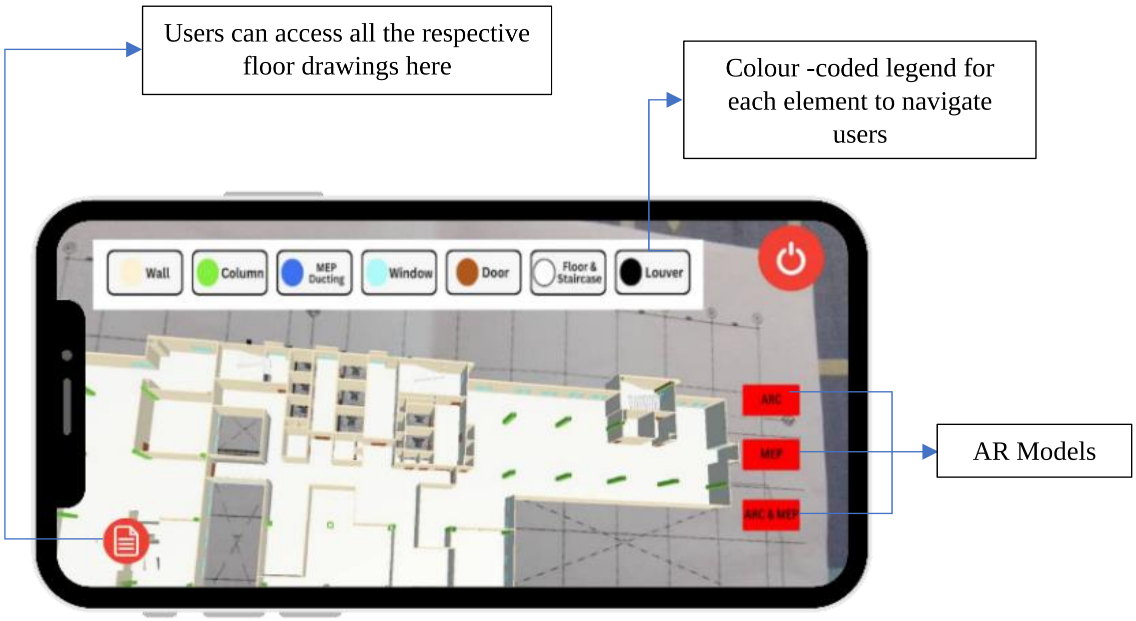


Figure 3.21: AR Interface

3.6 THE EFFECTIVENESS OF ARCHITECT3D MOBILE APPLICATION

The researcher conducted a quantitative survey through a questionnaire with 35 onsite professionals to achieve the objective of evaluating the effectiveness of the ARchitect3D mobile application. This evaluation involved a comparative analysis using data collected before and after the implementation of the mobile application. The questionnaire consisted of two sections. As shown in Appendix 2, section A focused on demography, and section B aimed to evaluate the effectiveness of the Architect3D mobile application. Section B included ten key variables which are construction waste, paper usage, cloud storage, 3D visualization, drawing interpretation, work productivity, cost management, communication & collaboration, sustainability, and outcome. The data will be analyzed using SPSS software.

Table 3.2: Cronbach’s Alpha Interpretation Scale (Streiner, 2003)

Cronbach’s Alpha	Interpretation
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.9$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

Table 3.3: Reliability Statistics

No. of Variables	Cronbach’s Alpha	Interpretation
10	0.968	Excellent

Table 3.2 shows Cronbach's Alpha ranges from 0 to 1, where higher values indicate greater reliability (Streiner, 2003). As shown in Table 3.3, the high Cronbach's Alpha value of 0.968 indicates excellent internal consistency of this study. This suggests that the responses are reliable and reflect a true measure of the application's effectiveness where ARchitect3D significantly enhances construction processes through the measured variables. These improvements are reflected in the higher mean scores of post-development, demonstrating the application's substantial positive impact on real construction scenarios.

3.7 CONCLUSION

In conclusion, the methodology implemented in this study effectively utilized innovative and quantitative approaches to address the core objectives. By conducting a survey with 30 on-site respondents, including project engineers, architects, site coordinators, and site supervisors, the researcher was able to identify critical client needs and problems on the SMCI project site. The data collected highlighted a significant lack of 3D visualization, leading to the development of the ARchitect3D mobile application using Unity 3D software. This application aims to enhance on-site 3D visualization and address the identified needs.

The effectiveness of the ARchitect3D mobile application was subsequently evaluated through another survey. The data from this evaluation, analyzed using SPSS software, provided valuable insights into the application's performance and its impact on addressing the site issues. This comprehensive research design, combining quantitative surveys with advanced software development and thorough data analysis, ensured a robust methodology to achieve the study's objectives and generate actionable insights.

CHAPTER 4
DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the analysis and interpretation of the data collected to address the objectives of the study. The primary objectives are:

a. To identify the client needs to overcome the problems on SMCI project site.
b. To develop 'ARchitect3D' mobile application using Unity software.
c. To evaluate the effectiveness of 'Architect3D' mobile application.

The first objective (a) focused on gathering insights from clients regarding the issues they encounter on the SMCI project site. The questionnaire targeted key stakeholders including engineers, site supervisors, and contractors, seeking to understand their daily challenges with traditional 2D drawings, which often lead to visualization difficulties, rework, and construction waste. The collected data provided a comprehensive understanding of the clients' needs and challenges, which are crucial for developing a targeted solution. This step ensured that the subsequent development of the application would directly address the real-world problems faced by users on the ground.

The second objective (b) involved the development of the ARchitect3D mobile application using Unity software. This development phase was guided by the insights gained from the first objective. The application was designed to enhance 3D visualization and interaction with architectural and engineering designs, thus overcoming the limitations of 2D drawings. The development process included several stages; conceptual design, coding, user interface design, and iterative testing. Each stage was crucial to ensure that the application was user-friendly, met the identified needs, and integrated seamlessly into existing workflows.

The third objective (c) aimed to evaluate the effectiveness of the ARchitect3D mobile application. After the development phase, another set of questionnaires was administered to the same group of stakeholders. These post-development questionnaires were designed to assess the application's effectiveness and its impact on addressing the previously identified problems. The evaluation criteria included ease of use, accuracy of 3D visualization, reduction in rework and construction waste, and overall improvement in project efficiency.

The results were analysed using SPSS software to provide quantitative evidence of the application's impact. The analysis focused on comparing pre- and post-implementation data to measure improvements in the aforementioned areas. Key metrics included mean scores for various effectiveness indicators and the reliability of the responses, validated through Cronbach's Alpha. The findings from these analyses are discussed in detail to draw meaningful conclusions and to provide recommendations for future improvements.

4.2 PROBLEM ENCOUNTERED IN SMCI PROJECT SITE

The researcher conducted a quantitative survey through a questionnaire with 30 on-site respondents to identify the client needs to overcome the problems on SMCI project site. Table 4.1 shows the demographics of all 30 respondents who participated in the survey.

Table 4.1: Respondent's Demography

No	Gender	No. of Respondents	Percentage
1	Male	19	63.33%
2	Female	11	36.67%
No	**Age**	**No. of Respondents**	**Percentage**
1	18-25 years old	0	0%
2	26-35 years old	12	40.00%
3	36-45 years old	9	30.00%
4	>45 years old	7	23.30%
No	**Designation**	**No. of Respondents**	**Percentage**
1	Project Engineer	13	43.30%
2	Site Coordinator	6	20.00%
3	Site Supervisor	9	30.00%
4	Architect	2	6.67%
No	**Experience**	**No. of Respondents**	**Percentage**
1	< 1 year	0	0%
2	1-5 years	10	33.33%
3	6-10 years	13	43.33%
4	> 10 years	7	23.33%

Based on Table 4.2, the survey results indicate unanimous agreement among all 30 participants that visualizing 2D drawings is challenging. This highlights a significant issue in the construction process on the SMCI project site, emphasizing the need for more intuitive and detailed 3D visualization tools to enhance comprehension and accuracy. Additionally, all 30 respondents (100%) reported experiencing delays or extensive rework due to unclear 2D construction details, underscoring the urgent need for adopting 3D visualization tools to improve clarity, reduce misunderstandings, and mitigate delays and rework.

Table 4.2: Identify Problems Encountered by SMCI Project Site

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Problem</th><th colspan="5">Response</th></tr>
<tr><th colspan="2">Yes</th><th colspan="3">No</th></tr>
<tr><td>1.</td><td>Hard to visualize 2D drawings</td><td colspan="2">100%</td><td colspan="3">0%</td></tr>
<tr><td>2.</td><td>Delays and extensive rework occurred due to lack of clarity in understanding 2D construction details</td><td colspan="2">100%</td><td colspan="3">0%</td></tr>
<tr><td>3.</td><td>Challenging in quickly obtain all the latest drawings in once centralized platform</td><td colspan="2">100%</td><td colspan="3">0%</td></tr>
<tr><td>4.</td><td>Utilizing a 3D visualization tool could help prevent misunderstandings, misinterpretations, and errors during the construction process</td><td colspan="2">100%</td><td colspan="3">0%</td></tr>
<tr><td rowspan="3">5.</td><td rowspan="3">Lack of comprehensive 3D views during construction</td><th colspan="5">Likert Scale</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>0%</td><td>0%</td><td>0%</td><td>23.33%</td><td>76.67%</td></tr>
</table>

Moreover, all 30 respondents (100%) find it difficult to quickly obtain all the latest drawings from a centralized platform. This unanimous response points to a significant inefficiency in the current system for accessing and managing construction drawings, suggesting a strong need for a more integrated and centralized digital platform to streamline access to up-to-date drawings and improve overall project coordination. The survey also indicates unanimous agreement that using 3D visualization tools could help prevent misunderstandings, misinterpretations, and errors during the construction process, highlighting the perceived value and potential benefits of such tools in projects like the SMCI project site.

Furthermore, the data shows that challenges due to the lack of comprehensive 3D views are frequent. Out of the 30 respondents, 23 (76.67%) reported facing these challenges very often, while 7 (23.33%) encountered them often. This pervasive problem emphasizes the need for better implementation and use of 3D visualization tools to enhance clarity and reduce construction-related issues. As a result, the researcher decided to develop an AR mobile application to enhance on-site 3D visualization.

4.3 THE EFFECTIVENESS OF ARCHITECT3D MOBILE APPLICATION

The researcher conducted a quantitative survey through a questionnaire with 35 onsite professionals to achieve the objective of evaluating the effectiveness of the ARchitect3D mobile application. This evaluation involved a comparative analysis using data collected before and after the implementation of the mobile application. The questionnaire consisted of two sections; Section A focused on demography and Section B aimed to evaluate the effectiveness of the ARchitect3D mobile application. Section B included ten key variables which are construction waste, paper usage, cloud storage, 3D visualization, drawing interpretation, work productivity, cost management, communication & collaboration, sustainability, and outcome. The responses are measured using a likert scale, with options ranging from "Strongly Disagree" to "Strongly Agree" as shown in Table 4.3. The data from Section B was analyzed using SPSS software. Overall, the survey results demonstrated that ARchitect3D effectively addressed key challenges and significantly enhanced the construction process on the SMCI project site.

Table 4.4 evaluates the satisfaction levels of 35 onsite professionals regarding various aspects of the existing method used before implementing the ARchitect3D mobile application, while Table 4.5 evaluates the satisfaction levels post-development of the application.

Table 4.3: Likert Scale (Joshi et al., 2015)

Likert Scale	
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Disagree	5

Table 4.4: Data of Pre-Development of Architect3D Mobile Application

No.	Pre-development of Architect3D mobile application		Likert Scale				
			Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
			1	2	3	4	5
1.	Construction Waste	Existing method generates less construction waste due to minimal rework at the site.	91.4%	8.6%	0%	0%	0%
2.	Paper Usage	Existing method uses a small amount of paper for printing and distributing 2D drawings for project reference and communication.	91.4%	8.6%	0%	0%	0%
3.	Cloud Storage	Existing method involves sending drawings via WhatsApp, which keeps drawings well-organized and easy to find.	91.4%	8.6%	0%	0%	0%
4.	3D Visualization	Existing method of visualizing floor plans with 2D drawings provides a clear and comprehensive understanding of design details.	91.4%	8.6%	0%	0%	0%
5.	Drawing Interpretation	Existing method rarely results in misinterpretation of drawings, ensuring minimal errors, rework, and delays in project execution.	91.4%	8.6%	0%	0%	0%
6.	Work Productivity	Existing method productivity is high, with the process of interpreting 2D drawings being quick and efficient, leading to timely task coordination and completion.	91.4%	8.6%	0%	0%	0%
7.	Cost Management	Existing method of managing costs related to errors and rework is straightforward and rarely impacted by misinterpretation of 2D drawings, keeping unexpected expenses to a minimum.	91.4%	8.6%	0%	0%	0%
8.	Communication & Collaboration	Existing method, which relies heavily on verbal explanations and 2D drawings, is effective in preventing misunderstandings and delays.	91.4%	8.6%	0%	0%	0%
9.	Sustainability	Existing method supports sustainability efforts, with minimal reliance on paper-based drawings and highly efficient communication methods, reducing waste and resource consumption.	91.4%	8.6%	0%	0%	0%
10.	Outcome	Existing method achieves desired outcomes efficiently, with 2D drawings being accurately interpreted, resulting in minimal errors, rework, and timely project completion.	91.4%	8.6%	0%	0%	0%

Table 4.5: Data of Post-development of Architect3D Mobile Application

No.	Post-development of Architect3D mobile application		Likert Scale				
			Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
			1	**2**	**3**	**4**	**5**
1.	Construction Waste	Using apps significantly reduces construction waste, as there is better 3D visualization of drawings and consequently less rework.	0%	0%	0%	8.6%	91.4%
2.	Paper Usage	By using apps, paper usage has decreased significantly, as all necessary drawings are accessible digitally.	0%	0%	0%	8.6%	91.4%
3.	Cloud Storage	By using apps, drawings are securely stored in cloud storage within the app, making it easier and more convenient to access.	0%	0%	0%	8.6%	91.4%
4.	3D Visualization	By using apps, the 3D visualization feature allows for a clearer understanding of floor plans.	0%	0%	0%	5.7%	94.3%
5.	Drawing Interpretation	By using apps, the 3D visualization feature provides a clearer and more intuitive understanding of floor plans, helping to minimize errors and delays.	0%	0%	0%	5.7%	94.3%
6.	Work Productivity	By using apps Work productivity has increased significantly, application allows for a quicker understanding of floor plans, enabling tasks to be coordinated and completed more efficiently.	0%	0%	0%	5.7%	94.3%
7.	Cost Management	By using apps, cost management has improved, as the application helps to identify potential errors early on, reducing the need for costly rework and minimizing unexpected expenses.	0%	0%	0%	5.7%	94.3%
8.	Communication & Collaboration	By using apps, ARchitect3D allows team members to better understand and communicate project details, leading to enhanced collaboration and fewer misunderstandings.	0%	0%	0%	5.7%	94.3%
9.	Sustainability	By using apps, we have reduced paper usage and minimized waste, contributing to a more sustainable construction process.	0%	0%	0%	5.7%	94.3%
10.	Outcome	By using apps, there is a clearer understanding of project plans, enabling better coordination, fewer errors, and smoother project execution.	0%	0%	0%	5.7%	94.3%

Table 4.6: Mean Score Interpretation Scale (Fazilah, 2008)

Mean Score	Interpretation of Mean Score
1.00 – 2.33	Low
2.34 – 3.67	Moderate
3.68 – 5.00	High

Table 4.7: Summary of Descriptive Statistics for Pre- and Post-Development of ARchitect3D

Variables	Pre-Development		Post-Development	
	Mean	Interpretation of Mean Score	Mean	Interpretation of Mean Score
Construction Waste	1.17	Low	4.91	High
Paper Usage	1.11	Low	4.94	High
Cloud Storage	1.14	Low	4.97	High
3D Visualization	1.09	Low	4.97	High
Drawing Interpretation	1.11	Low	4.94	High
Work Productivity	1.11	Low	4.91	High
Cost Management	1.09	Low	4.94	High
Communication & Collaboration	1.09	Low	4.94	High
Sustainability	1.11	Low	4.91	High
Outcome	1.09	Low	4.94	High

Table 4.8: Paired Sample t-Test

Variable	Mean	Std. Deviation	t	Significant (Two-sided) p
Construction Waste	3.74	0.505	43.810	<.001
Paper Usage	3.83	0.453	50.021	<.001
Cloud Storage	3.83	0.382	59.234	<.001
3D Visualization	3.87	0.404	56.935	<.001
Drawing Interpretation	3.83	0.453	50.021	<.001
Work Productivity	3.80	0.473	47.550	<.001
Cost Management	3.86	0.430	53.072	<.001
Communication & Collaboration	3.86	0.430	53.072	<.001
Sustainability	3.80	0.531	42.308	<.001
Outcome	3.86	0.430	53.072	<.001

The summary of descriptive statistics for both the pre- and post-development phases of the ARchitect3D application is provided in Table 4.7 with the mean score interpretation scale outlined in Table 4.6. Prior to the implementation of ARchitect3D, all variables exhibited low levels of effectiveness, with mean scores ranging from 1.09 to 1.17. This indicates that the existing methods for construction waste management, paper usage, cloud storage, 3D visualization, drawing interpretation, work productivity, cost management, communication & collaboration, sustainability, and overall project outcomes were perceived as ineffective.

Conversely, post-development of ARchitect3D, there was a substantial improvement across all variables, with mean scores dramatically increasing to 4.91 to 4.97. These scores indicate a significantly higher level of effectiveness, categorized as High according to the interpretation scale. This improvement suggests that ARchitect3D successfully enhanced various aspects of construction processes, from visualization and productivity to sustainability and overall project outcomes. It is noteworthy that the highest mean indicates most respondents agreed on that variable (Stehlik-Barry and Babinec, 2017).

Paired sample t-test is a statistical method used to compare the mean of two measurements taken from the same individual, object or related units (Manfei et al., 2017). In Table 4.8, the results of paired sample t-test reveal a statistically significant difference between the mean scores of variables pre- and post-development of the ARchitect3D application across all dimensions. The mean scores for all variables range from 3.74 to 3.87, indicating a notable improvement post-development of the ARchitect3D application.

Additionally, the standard deviations are relatively low, suggesting consistency in the observed improvements across these variables. Dankel and Loenneke (2021), states that a high t-value indicates a large difference between paired samples relative to the variability of the differences. The high t-values as shown in Table 4 for each variable further emphasize a significant difference between the pre- and post-development phases. According to Denis (2018), a p-value less than 0.001 in a t-test indicates statistical significance. In line with this, the p-values for all variables are less than 0.001, providing robust evidence that the ARchitect3D application has been effective and positively impacted construction processes.

4.4 DISCUSSION

Based on the data analysis, the objective of this study is achieved. The post-development of the ARchitect3D mobile application exhibits significantly higher mean scores compared to the utilization of the existing method, indicating its effectiveness in real construction scenarios. According to Morgan et al. (2019), a higher mean score signifies widespread agreement among respondents regarding the positive impact of the variable under consideration. It is observed that the variable for 3D visualization has the highest mean score of 3.87. This suggests that the utilization of the ARchitect3D application has contributed significantly to enhancing 3D visualization capabilities during the construction process. Consequently, this improved visualization has led to a reduction in construction waste, as it allows for better understanding and interpretation of architectural drawings, thereby minimizing the need for rework. This finding underscores the practical benefits of employing AR technology in construction projects, aligning with the broader industry trend towards digitalization and innovation.

4.5 CONCLUSION

The study successfully addressed the challenges faced by the construction industry, particularly within the SMCI project site, through the development and evaluation of the ARchitect3D mobile application. Initially, client needs were identified via a detailed survey, revealing issues with traditional 2D drawings, such as poor visualization, frequent rework, and increased construction waste. In response, the ARchitect3D application was developed using Unity software, focusing on improving 3D visualization and interaction with designs. The effectiveness of the application was then assessed through additional surveys and analyzed using SPSS software. The results indicated significant improvements, including reduced construction waste, lower paper usage, enhanced 3D visualization, better drawing interpretation, increased productivity, improved cost management, and enhanced communication. Overall, ARchitect3D significantly enhances construction practices, aligning with the transformative advancements of Industry Revolution 4.0, and represents a substantial step towards more sustainable and efficient construction processes.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter, we present the culmination of our study on the ARchitect3D mobile application, offering comprehensive insights into its impact and recommendations for further enhancement. The ARchitect3D application represents a pivotal advancement in digital tools for the construction industry, leveraging augmented reality (AR) to revolutionize project visualization, accuracy, and efficiency.

Throughout our research, we have examined how ARchitect3D addresses critical shortcomings of traditional 2D drawings, which often suffer from poor visualization capabilities and contribute to increased construction waste and frequent rework. By transitioning to a 3D AR environment, the application has demonstrated significant improvements in spatial comprehension and design validation, thereby mitigating these challenges and promoting more streamlined construction processes.

The findings underscore the transformative potential of ARchitect3D in enhancing project management and execution. Through detailed analysis and user feedback, we have identified key areas where the application excels and where further improvements can be made. These insights have informed our recommendations, aimed at maximizing the application's utility and adaptability in real-world construction scenarios.

The study's methodology involved rigorous testing and evaluation of ARchitect3D across various construction settings, evaluating its usability, performance, and integration capabilities. The application's high reliability score of 0.968, based on internal consistency metrics, reaffirms its robust performance and effectiveness in facilitating informed decision-making and precise project execution.

As we delve into the conclusions drawn from our research, we highlight not only the strengths of ARchitect3D but also the actionable steps needed to address any identified limitations. By offering clear, implementable recommendations, we aim to propel ARchitect3D towards even greater utility and relevance in the construction industry.

Ultimately, this chapter sets the stage for understanding how ARchitect3D stands as a catalyst for advancing digital construction technologies. It underscores the application's role in fostering sustainability, efficiency, and innovation within the built environment. By embracing these insights and recommendations, stakeholders can harness the full potential of ARchitect3D to achieve superior project outcomes and drive continued progress in the construction industry.

5.2 RECOMMENDATION

Based on our comprehensive study of the ARchitect3D mobile application and its impact on construction processes, several strategic recommendations have been identified to further enhance its functionality and maximize its benefits within the industry.

Firstly, it is recommended to develop a web-based version of ARchitect3D. This initiative aims to alleviate the storage constraints often associated with mobile devices and enhance accessibility across different platforms. By migrating certain functionalities to the web, such as model rendering and data storage, users would gain the flexibility to access and collaborate on projects seamlessly from desktops or tablets, thereby promoting more efficient project management and facilitating broader project team collaboration.

Secondly, the integration of precise measurement tools directly within the 3D model is crucial for enhancing the application's practical utility on construction sites. Enabling users to take accurate measurements of distances, dimensions, and angles within the augmented reality environment can significantly improve on-site decision-making and ensure adherence to design specifications. This feature would empower construction professionals to verify spatial requirements and make informed adjustments swiftly, thereby minimizing errors and optimizing project timelines.

Customizability of the AR interface emerges as another key recommendation. By allowing users to personalize their ARchitect3D experience according to specific project needs and individual preferences, the application can enhance user engagement and workflow efficiency. Customization options could include adjusting display settings, modifying control gestures, or selecting preferred visualization modes. Such flexibility not only accommodates diverse project requirements but also enhances user satisfaction by tailoring the interface to align closely with user preferences and operational workflows.

Furthermore, the inclusion of annotation tools and a snipping tool within ARchitect3D can greatly enhance collaboration and communication among project stakeholders. Annotation tools would enable users to add notes, comments, or instructions directly onto 3D models within the AR environment, facilitating real-time communication of design intent or construction requirements. Similarly, a snipping tool for capturing and sharing images of the AR environment allows users to document project progress, highlight specific issues, or communicate visual information effectively with team members or clients, thereby improving transparency and clarity in project communication.

Lastly, enhancing the security of ARchitect3D through the integration of biometric authentication methods is essential to safeguard sensitive project data and protect against unauthorized access. By implementing robust authentication protocols, such as fingerprint scanning or facial recognition, the application can enhance user authentication processes and mitigate potential risks associated with data breaches or unauthorized usage. Strengthening security measures not only instills confidence in users regarding the application's reliability but also ensures the integrity and confidentiality of project information throughout its lifecycle.

In conclusion, these recommendations are strategically aligned to elevate the functionality, usability, and security of the ARchitect3D mobile application, positioning it as a versatile and indispensable tool for modern construction practices. By prioritizing these enhancements, stakeholders can leverage ARchitect3D to achieve enhanced project outcomes, optimize resource utilization, and drive innovation within the construction industry.

5.3 CONCLUSION

In conclusion, the study illuminates the profound impact of the ARchitect3D mobile application on modern construction practices, heralding a transformative shift in project visualization, efficiency, and sustainability. ARchitect3D has emerged as a pivotal tool in addressing longstanding challenges associated with traditional 2D drawings, offering construction professionals enhanced spatial visualization, precise decision-making capabilities, and streamlined project coordination.

The application's utilization of 3D augmented reality environments not only enhances the realism and accuracy of project representations but also contributes significantly to reducing construction waste and optimizing resource allocation. By minimizing design errors and facilitating real-time collaboration among project stakeholders, ARchitect3D plays a crucial role in improving project efficiency and cost-effectiveness across diverse construction settings.

Aligned with Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure), ARchitect3D exemplifies how technological innovation can drive sustainable industrialization and foster innovation in construction practices. By leveraging augmented reality technology, the application supports the development of resilient infrastructure, promotes inclusive and sustainable industrialization, and encourages innovation in construction methods and project management.

Furthermore, ARchitect3D contributes to Sustainable Development Goal 11 (Sustainable Cities and Communities) by enhancing urban planning, resilience, and sustainability within built environments. The application empowers urban planners and architects to design more sustainable and inclusive cities, leveraging advanced visualization tools to create efficient spatial layouts and optimize urban infrastructure development. By promoting sustainable building practices and improving the efficiency of construction projects, ARchitect3D aligns with global efforts to create livable, resilient, and sustainable cities for all.

Looking ahead, the recommendations outlined in this study provide a strategic pathway for enhancing ARchitect3D's functionality, usability, and security. Initiatives such as developing a web-based version, integrating precise measurement tools, customizing the AR interface and enhancing security through biometric authentication aim to further elevate the application's impact and relevance in the construction industry.

By embracing these recommendations, stakeholders can harness ARchitect3D's full potential to achieve superior project outcomes, optimize resource utilization, and drive innovation in urban development and infrastructure projects. As the construction industry continues to embrace digital transformation, ARchitect3D stands poised to lead the charge towards more sustainable, efficient, and resilient built environments.

In essence, ARchitect3D represents not only a technological advancement but also a strategic enabler of sustainable development, supporting global initiatives to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster sustainable urbanization. By leveraging augmented reality technology, ARchitect3D embodies the future of construction practices, where innovation, efficiency, and sustainability converge to create cities and communities that are equitable, resilient, and future-ready.

REFERENCE

Aarlien, D. (2021). End-user development interfaces for creation of virtual 3D environments (Master's thesis).

Al Husaini, M. A. (2021). Implementation Of Mobile Bimx System On Uma Kabuong Limo House Virtual Restoration. Jurnal Mantik, 5(2), 1006-1015.

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Mohammed, B. S. (2018). Industry revolution IR 4.0: future opportunities and challenges in construction industry. In MATEC web of conferences (Vol. 203, p. 02010). EDP Sciences.

Alaloul, W. S., Saad, S., & Qureshi, A. H. (2022). Construction Sector: IR 4.0 Applications. In Handbook of Smart Materials, Technologies, and Devices: Applications of Industry 4.0 (pp. 1341-1390). Cham: Springer International Publishing.

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. Procedia Engineering, 164, 487-494.

Cernev, T., & Fenner, R. (2020). The importance of achieving foundational Sustainable Development Goals in reducing global risk. Futures, 115, 102492.

Chen, K., & Xue, F. (2022). The renaissance of augmented reality in construction: history, present status and future directions. Smart and Sustainable Built Environment, 11(3), 575-592.

Côté, S., Trudel, P., Snyder, R., & Gervais, R. (2013). An augmented reality tool for facilitating on-site interpretation of 2D construction drawings. In Proceedings of the 13th International Conference on Construction Applications of Virtual Reality (CONVR), London, UK (Vol. 316, p. 323).

Dankel, S. J., & Loenneke, J. P. (2021). Effect sizes for paired data should use the change score variability rather than the pre-test variability. The Journal of Strength & Conditioning Research, 35(6), 1773-1778.

Denis, D. J. (2018). SPSS data analysis for univariate, bivariate, and multivariate statistics. John Wiley & Sons.

Denney, A. S., & Tewksbury, R. (2013). How to write a literature review. Journal of criminal justice education, 24(2), 218-234.

Dreimane, L. F., & Zālīte-Supe, Z. (2022). Teaching interior design in augmented reality. Proceedings of the Human, Technologies and Quality of Education, 169-180.

Dunston, P. S., & Wang, X. (2005). Mixed reality-based visualization interfaces for architecture, engineering, and construction industry. Journal of construction engineering and management, 131(12), 1301-1309.

Fazilah, (2008). The Influence of Individual Attributes on Inter-Ethnic Tolerance among Early Youth in Selangor, PhD Dissertation, Universiti Putra Malaysia, Selangor

Ferrandiz, J., Banawi, A., & Peña, E. (2018). Evaluating the benefits of introducing "BIM" based on Revit in construction courses, without changing the course schedule. Universal Access in the Information Society, 17, 491-501.

Gallaway, T. O., & Starkey, J. (2013). Google Drive. The Charleston Advisor, 14(3), 16-19.

Igarashi, T., & Hughes, J. F. (2007). A suggestive interface for 3D drawing. In ACM SIGGRAPH 2007 courses (pp. 20-es).

Jerald, J., Giokaris, P., Woodall, D., Hartholt, A., Chandak, A., & Kuntz, S. (2014). Developing virtual reality applications with Unity. In 2014 IEEE Virtual Reality (VR) (pp. 1-3). IEEE.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. British journal of applied science & technology, 7(4), 396-403.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. Process safety and environmental protection, 117, 408-425.

Khan, R. A., Liew, M. S., & Ghazali, Z. B. (2014). Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status. Procedia - Social and Behavioral Sciences, 109, 507–513.

Khawas, C., & Shah, P. (2018). Application of firebase in android app development-a study. International Journal of Computer Applications, 179(46), 49-53.

Kumari, S. K. V., Lavanya, K., Vidhya, V., Premila, G. A. D. J. S., & Lawrence, B. (2023).

Research methodology (Vol. 1). Darshan Publishers.

Manfei, X. U., Fralick, D., Zheng, J. Z., Wang, B., & Changyong, F. E. N. G. (2017). The differences and similarities between two-sample t-test and paired t-test. Shanghai archives of psychiatry, 29(3), 184.

Morgan, G. A., Barrett, K. C., Leech, N. L., & Gloeckner, G. W. (2019). IBM SPSS for introductory statistics: Use and interpretation. Routledge.

Shih, N. J. (2001). A study of 2D-and 3D-oriented architectural drawing production methods. Automation in Construction, 5(4), 273-283.

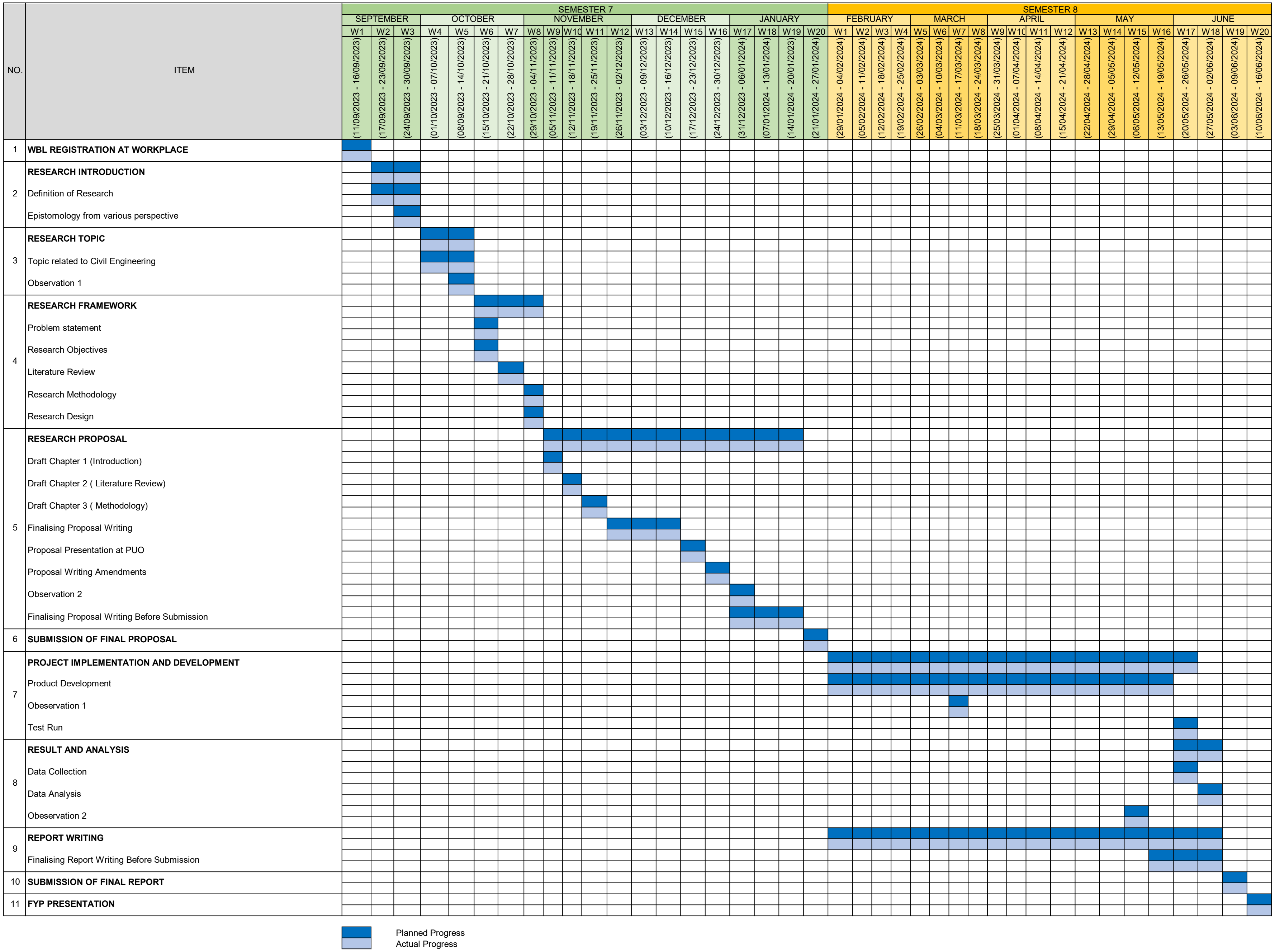
Stehlik-Barry, K., & Babinec, A. J. (2017). Data analysis with IBM SPSS statistics. Packt Publishing Ltd.

Streiner, D. L. (2003). Being inconsistent about consistency: When coefficient alpha does and doesn’t matter. J Pers Assess, 80(3), 217-222.

Thomas, C. G. (2021). Research methodology and scientific writing. Thrissur: Springer.

Xiao, C., & Lifeng, Z. (2014). Implementation of mobile augmented reality based on Vuforia and Rawajali. In 2014 IEEE 5th International Conference on Software Engineering and Service Science (pp. 912-915). IEEE.

APPENDIX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NO.
ITEM
1 WBL REGISTRATION AT WORKPLACE
2 RESEARCH INTRODUCTION
Definition of Research
Epistomology from various perspective
3 RESEARCH TOPIC
Topic related to Civil Engineering
Observation 1
4 RESEARCH FRAMEWORK
Problem statement
Research Objectives
Literature Review
Research Methodology
Research Design
5 RESEARCH PROPOSAL
Draft Chapter 1 (Introduction)
Draft Chapter 2 (Literature Review)
Draft Chapter 3 (Methodology)
Finalising Proposal Writing
Proposal Presentation at PUO
Proposal Writing Amendments
Observation 2
Finalising Proposal Writing Before Submission
6 SUBMISSION OF FINAL PROPOSAL
7 PROJECT IMPLEMENTATION AND DEVELOPMENT
Product Development
Obeservation 1
Test Run
8 RESULT AND ANALYSIS
Data Collection
Data Analysis
Obeservation 2
9 REPORT WRITING
Finalising Report Writing Before Submission
10 SUBMISSION OF FINAL REPORT
11 FYP PRESENTATION
Planned Progress
Actual Progress

SMCI Project Site Feedback Survey

Hello everyone, I'm Muugesh, a final-year student pursuing a Bachelor of Civil Engineering Technology with Honours at Ungku Omar Polytechnic. Currently, I am undergoing Work-Based Learning (WBL) at Sunway Construction Sdn Bhd. As part of my BCT70285 course, this questionnaire is aimed at identifying the problems encountered on the SMCI project site, with a focus on the utilization of 3D visualization in the construction process.

Thank you for participating in this survey. Your valuable insights play a crucial role in enhancing our understanding of the challenges faced on this project site.

* Indicates required question

SECTION A

Demographic

1. Gender *

Mark only one oval.

- Male
- Female

2. Age *

Mark only one oval.

- 18-25 years old
- 26-35 years old
- 36-45 years old
- > 45 years old

3. Designation *

Mark only one oval.

- Project Engineer
- Site Coordinator
- Site Supervisor
- Architect
- Other: ____________________

4. Work Experience *

Mark only one oval.

- < 1 year
- 1-5 years
- 6-10 years
- > 10 years

SECTION B

Identifying the problems encountered on the SMCI project site

5. Did you find it hard to visualize 2D drawings? *

Mark only one oval.

- Yes
- No

6. How often do you face challenges due to the lack of comprehensive 3D views during construction? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Very Often

7. Have delays or extensive rework occurred due to a lack of clarity in understanding 2D construction details? *

Mark only one oval.

◯ Yes
◯ No

8. Do you find it challenging to quickly obtain all the latest drawings in one centralized platform *

Mark only one oval.

◯ Yes
◯ No

9. Do you think that utilizing a 3D visualization tool could help prevent misunderstandings, misinterpretations, and errors during the construction process? *

Mark only one oval.

◯ Yes
◯ No

ARCHITECT3D MOBILE APPLICATION

Hello everyone, I'm Muugesh, a final-year student pursuing a Bachelor of Civil Engineering Technology with Honours at Ungku Omar Polytechnic. Currently, I am undergoing Work-Based Learning (WBL) at Sunway Construction, while simultaneously working on my final year project (FYP). I am conducting research aimed at developing an augmented reality (AR) mobile application named ARchitect3D to address the lack of 3D visualization, which contributes to misinterpretation on construction sites. This questionnaire is to evaluate the effectiveness of the ARchitect3D mobile application. Your valuable insights will help us evaluate the effectiveness of the application in real-world construction scenarios.

* Indicates required question

Overview video of the ARchitect3D mobile application

Respondents are encouraged to either click on a provided link or scan a QR code to view a brief preview of the ARchitect3D mobile application for a better understanding of the application before proceeding with answering the questionnaire. Thank you.

Link: https://drive.google.com/file/d/17Q9eAnYIIhM5odUVQR6OPeL-TcazN8vI/view?usp=sharing

Scan to view:

SECTION A - DEMOGRAPHIC

1. Gender *

Mark only one oval.

- ( ) Male
- ( ) Female

2. Age *

Mark only one oval.

- ⬭ 18-25 years old
- ⬭ 26-35 years old
- ⬭ 36-45 years old
- ⬭ > 45 years old

3. What is your role or position on the construction project? *

Mark only one oval.

- ⬭ Project Engineer
- ⬭ Site Coordinator
- ⬭ Site Supervisor
- ⬭ Architect
- ⬭ Other: ______________________________

4. How many years of experience do you have in the construction industry? *

Mark only one oval.

- ⬭ < 1 year
- ⬭ 1-5 years
- ⬭ 6-10 years
- ⬭ > 10 years

SECTION B - EVALUATE THE EFFECTIVENESS OF ARCHITECT3D MOBILE APPLICATION

Likert Scale

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

5. Existing method generates less construction waste due to minimal rework at the site. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

6. Using apps significantly reduces construction waste, as there is better 3D visualization of drawings and consequently less rework. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

7. Existing method uses a small amount of paper for printing and distributing 2D drawings for project reference and communication. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

8. By using apps, paper usage has decreased significantly, as all necessary drawings are accessible digitally. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

9. Existing method involves sending drawings via WhatsApp, which keeps drawings well-organized and easy to find. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

10. By using apps, drawings are securely stored in cloud storage within the app, making it easier and more convenient to access. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

11. Existing method of visualizing floor plans with 2D drawings provides a clear and comprehensive understanding of design details. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

12. By using apps, the 3D visualization feature allows for a clearer understanding of floor plans. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

13. Existing method rarely results in misinterpretation of drawings, ensuring minimal errors, rework, and delays in project execution. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

14. By using apps, the 3D visualization feature provides a clearer and more intuitive understanding of floor plans, helping to minimize errors and delays. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

15. Existing method productivity is high, with the process of interpreting 2D drawings being quick and efficient, leading to timely task coordination and completion. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

16. By using apps work productivity has increased significantly, application allows for a quicker understanding of floor plans, enabling tasks to be coordinated and completed more efficiently. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

17. Existing method of managing costs related to errors and rework is straightforward and rarely impacted by misinterpretation of 2D drawings, keeping unexpected expenses to a minimum. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

18. By using apps, cost management has improved, as the application helps to identify potential errors early on, reducing the need for costly rework and minimizing unexpected expenses. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

19. Existing method, which relies heavily on verbal explanations and 2D drawings, is effective in preventing misunderstandings and delays. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

20. By using apps, ARchitect3D allows team members to better understand and communicate project details, leading to enhanced collaboration and fewer misunderstandings. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

21. Existing method supports sustainability efforts, with minimal reliance on paper-based drawings and highly efficient communication methods, reducing waste and resource consumption. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

22. By using apps, we have reduced paper usage and minimized waste, contributing to a more sustainable construction process. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

23. Existing method achieves desired outcomes efficiently, with 2D drawings being accurately interpreted, resulting in minimal errors, rework, and timely project completion. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

24. By using apps, there is a clearer understanding of project plans, enabling better coordination, fewer errors, and smoother project execution. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

SECTION C - SUGGESTIONS & RECOMMENDATION

25. Suggestions and recommendation that may add in the development of this ARchitect3D mobile application.