Universiti Teknologi MARA Cawangan Perak

ISCU 2025

17TH RISM INTERNATIONAL SURVEYING CONFERENCE FOR UNDERGRADUATES

Embracing Construction Revolution 4.0 (CR4.0): Transforming Malaysia's Built Environment

16th - 17th May 2025 I Friday - Saturday

E-ISBN PROCEEDING

VOLUME II

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Published by
Royal Institution of Surveyors Malaysia
3rd Floor, Bangunan Juurukur
64 & 66, Jalan 52/4
46200 Petaling Jaya
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Perpustakaan Negara Malaysia Data-Pengkatalogan-dalam-Penerbitan

E- PROCEEDING 17th RISM ISCU 2025 Volume II

Editors: Lizawati Abdullah, Nor Suzila Lop, Nor Nazihah Chuweni, Suriani Ngah Abdul Wahab, Hasnan Hashim

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eISBN 978-629-94789-1-1

9 786299 478911

(online)

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WELCOME SPEECH FROM THE CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

بسم الله الرحمن الرحيم

السلام عليكم ورحمة الله وبركاته

Greetings to all,

It is with great pleasure that I welcome you to the 17th RISM International Surveying Conference for Undergraduates (ISCU 2025), themed *"Embracing Construction Revolution 4.0: Transforming Malaysia's Built Environment."* On behalf of the Royal Institution of Surveyors Malaysia (RISM), I also wish to express our sincere appreciation to Universiti Teknologi MARA (UiTM), Perak Campus, for graciously hosting this significant event.

As we navigate the era of the Fourth Industrial Revolution (IR4.0)—or in our context, Construction Revolution 4.0 (CR4.0)—we are witnessing transformative advancements across the global construction sector. Technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, and cloud computing are redefining the way we build, manage, and interact with our built environment. For Malaysia, embracing CR4.0 is a strategic imperative to achieve our socio-economic and environmental goals.

This conference serves as a vital platform to unite surveying undergraduates from various disciplines, fostering critical dialogue on industry challenges, enhancing professional networking, and preparing a new generation of talent for the rapidly evolving construction landscape. It is also an opportunity for employers to engage with and inspire our future professionals.

I would like to extend my heartfelt thanks to all industry speakers, paper presenters, judges, and participants for their time, contributions, and support in making ISCU 2025 a success. I also commend the organising committee for curating a meaningful and dynamic conference experience.

May the knowledge gained, connections formed, and ideas exchanged during this event inspire all participants to lead and innovate in their future endeavours.

Wishing everyone a productive and memorable conference.

Prof. Ts Sr Dr. Adi Irfan Bin Che Ani'
Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM CO-CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

Bismillahirrahmanirrahim.

السلام عليكم ورحمة الله وبركاته and greetings to all.

It is my great pleasure to welcome everyone to the 17th International Surveyor Conference for Undergraduates (ISCU 2025), proudly hosted by Universiti Teknologi MARA (UiTM) Perak Branch in collaboration with the Royal Institution of Surveyors Malaysia (RISM). This event is a meaningful platform for students in the built environment to share ideas, showcase innovations, and build professional networks. We are honoured by your presence and enthusiastic participation, with 135 accepted papers and 78 poster presentations this year.

UiTM Perak, home to the College of Built Environment, has long been a hub for academic excellence in architecture, planning, and surveying. Our commitment remains strong in nurturing competent graduates who meet industry demands and contribute to nation-building.

While you're here, we invite you to experience the heritage and culture of Perak Tengah from the architectural richness of Rumah Kutai to the historical towns of Pasir Salak, Bota, and Kampung Gajah.

To all presenters and winners, congratulations on your achievements. Let your work today be a catalyst for future success and academic growth. We hope this conference will inspire you to explore new ideas, foster collaboration, and make lasting memories.

My deepest thanks to the Royal Institution of Surveyors Malaysia (RISM) and the organising committee for making this event a success.

We hope your experience here will be rewarding and unforgettable.

Thank you. Selamat datang dan selamat berjaya.

Associates Professor Dr. Nur Hisham Ibrahim, *PMP*
Co-Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM THE PROJECT DIRECTOR

RISM 17th International Surveying Conference for Undergraduates 2025

Alhamdulillah, all praise to Allah S.W.T. for His guidance and blessings in making the RISM 17th International Surveying Conference for Undergraduates (ISCU) 2025 a reality.

It is with great honour and gratitude that I welcome all participants, guests, academicians, and industry professionals to this prestigious event, proudly organized under the Royal Institution of Surveyors Malaysia (RISM). This 17th edition of ISCU stands as a proud testament to our collective dedication toward academic excellence, professional collaboration, and youth empowerment in the field of surveying.

I extend my heartfelt appreciation to RISM for its unwavering support, to the hardworking ISCU 2025 Organising Committee, and to all 16 partnering universities across Malaysia for their commitment and contributions. Your efforts have shaped this conference into a dynamic platform for knowledge exchange, innovation, and professional growth.

To the academicians and practitioners present, your insights are invaluable in bridging the gap between academic theory and real-world practice. To our undergraduate participants, your passion, curiosity, and commitment are the very foundation of our future. May this conference not only deepen your academic journey but also ignite a spirit of leadership, integrity, and sustainable thinking.

Let this gathering serve as more than an academic milestone. May it foster lifelong networks, inspire transformative ideas, and chart new directions in our shared professional journey.

Wishing everyone a rewarding and inspiring conference experience.

Sr Dr. Nurul Fadzila Zahari
Project Director
RISM 17th ISCU 2025

EVALUATING DEPTH ACCURACY OF GROUND PENETRATING RADAR IN WET AND DRY SOIL CONDITIONS

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ABSTRACT

Accuracy assessment in Ground Penetrating Radar (GPR) is crucial in improving subsurface detection in various geophysical and engineering applications including both metallic and non-metallic materials. GPR analyzes the ground by emitting electromagnetic pulses at various frequencies, but reflected signals often contain unwanted echoes due to soil variability and buried utilities. This study to evaluate the accuracy of GPR data for buried object such as PVC and metal pipes under wet and dry soil conditions. The objective is to evaluate the accuracy of depth values of metal and PVC pipes between the wet and dry soil condition using the RMSE formula and to propose the best practice in the radargram enhancement dataset on wet and dry soil condition for depth penetration accuracy using the ReflexW Software. A UTSI Trivue GPR instrument with a high frequency (1 GHz) will be employed, and the resulting radargram images will undergo post-processing in ReflexW Software to ensure accurate final depth measurements. Additionally, ReflexW Software will be used to enhance radargram quality by incorporating migration techniques to refine depth estimations for both soil conditions and pipe materials. A controlled experimental setup is designed, where a playwood barrier separates wet and dry soil compartments. Metal and PVC pipes, each measuring 1.5 meters in length and placed 0.4 meters apart, are embedded at a fixed depth between 0.2-0.5 meters. The GPR will detecting the pipes in 3 different permittivity value which is 8 as default, 10 for dry and 20 wet conditions. Radargram images are processed in both 2D and 3D using ReflexW Software, applying standard enhancement techniques such as seven key processing parameters. Additionally, a customized migration processing technique is introduced to refine subsurface object localization and correct hyperbola distortions beyond conventional methods. After implementing all enhancement techniques, a best-practice guideline will be developed in table format to facilitate real-world applications.

Keywords: Accuracy Assessment, GPR, Wet and Dry Soil Condition, ReflexW Software, Migration Techniques

I. INTRODUCTION

Underground exploration on the buried mapping soil layers and assessing underground utility have been done extensively by using Ground Penetrating Radar (GPR). In the previous study, the depth produced by the GPR is influenced by the soil condition, respectively, with their moisture levels that will change the GPR signal due to their higher dielectric constant. The wetter the soil conditions that need to be measured, the stronger the reflection that the GPR signal needs to face. From that statement, the depth and radargram that are produced by the GPR will have some error during the signal time travel because of attenuation or delayed return of radar signals (Huisman et al., 2003).

Furthermore, ground-penetrating radar survey is one of the uncommon methods in the surveying field in Malaysia that lacks expertise on the instrument known as GPR and their procedure because it is totally different from other types of surveying like cadastral, engineering, and hydrography. By this statement, the studies and research have been performed to recognize and identify limitations, accessibility, accuracy, and characteristics to maximize the uses of ground-penetrating radar in surveying. For example, evaluate the depth accuracy produced by the GPR equipment with the different soil moisture levels, such as dry, semi-dry, and wet (Nordin et al., 2022).

In addition, during the underground detection by using Ground Penetrating Radar, it will have several important parts that need to be highlighted, which are the dielectric constant of the subsurface materials because

it can influence the signal strength and give an impact to the depth accuracy as the final result. In the sandy soils, accuracy of depth can be upgraded in both dry and wet conditions, as these soils allow a better penetration of radar signals due to lower water retention and decreased dielectric constant (Cassidy, 2009).

In the processing part, which is in enhancing the radargram image, the suitable processing parameters need to be carried out to maximize the information from the radargram image, with respect to considering the types of soil conditions of the ground coverage on the site measurement area. The other factor that needs to be considered is the weather and humidity of the surrounding area, which will affect the permittivity of soil and change the dielectric constants of soil. This research will identify the accuracy assessment of depth by using ground-penetrating radar on the wet and dry soil conditions. The process and result will be conducted, discussed, and elaborated.

II. PROBLEM STATEMENT

Ground Penetrating Radar (GPR) has become a vital tool for detecting underground cables and utilities. However, its accuracy can be heavily affected by soil conditions especially in wet environments. Wet soil has a much higher dielectric constant around 80, compared to dry soil, which typically falls between 3 and 10. This difference makes it harder for GPR signals to penetrate deeply and clearly, leading to challenges in measuring accurate depths. The situation is further complicated by the wide range of materials used for underground pipes today, both metallic and non-metallic, which can interact differently with radar signals and affect detection accuracy (Mohd Kamal et al., 2020). In Malaysia, where the climate is tropical, soil moisture can vary drastically throughout the year. Heavy rain during the wet season and intense heat during the dry season make soil conditions unpredictable (Abdul Rahman, 2018). These fluctuations impact GPR performance and create additional challenges for surveyors trying to get reliable results in the field.

Accurate depth detection not only depends on field conditions, but it also relies on how the data is processed afterwards. Post-processing techniques, such as radargram analysis, are essential for improving the quality of results. There are many different algorithms available, each designed for specific purposes like archaeology, geology, or structural analysis (Ulapane et al., 2019). However, for utility detection, especially in Malaysia's humid climate, it's still unclear which processing methods are the most suitable. The Malaysian Meteorological Department, (2024) reports that relative humidity can range from 10% to 90%, depending on location and season, further complicating the situation.

Even though GPR is widely used, there is still a lack of focused research on how well it performs in Malaysia, especially in wet and dry soil conditions. There is also no standard guideline or recommended processing technique that fits the local environment. This gap makes it difficult for surveyors to consistently get accurate results, especially during extreme weather. It proves that this research is important to test and improve the use of GPR under different soil moisture conditions and to make the job of detecting underground cables more effective and reliable.

III. LITERATURE REVIEW

Underground utility mapping involves the determining, positioning, and labelling of various public utilities located on the ground's surface. The application that is produced from this process is by detecting subsurface objects such as telecommunication, electrical cables, sewage pipelines, gas pipelines, water and the other essential infrastructure that exists below a subsurface (Jamil et al., 2015). The post-processing software and data acquisition play the important role in mapping and identifying underground utilities by using the post-processing tool. By using it, operators can determine the true path of buried utility cables such as power cables, telecommunication cables and pipelines, whether metal or non-metallic (Nordin et al., 2022).

Furthermore, in detection work for utility mapping, the common instrument which Ground Penetrating Radar is widely used in this fieldwork because of the radar signal that is produced from the GPR can penetrate along the subsurfaces that will detect an underground object such as a cable or pipeline with the efficient depth accuracy. Other than that, the depth and location on the surface after the detection will be marked for the next procedure, which is to collect the position with the Global Positioning System (GPS) and map the position in the plan known as the utility plan (Abubakari & Richmond, 2023). Nowadays, a demand for underground utility service increases because of more and more utilities being buried with the increase of urban development. The mapping work becomes tougher due to the irresponsible people that take this situation without any consent by creating some problems in the underground surface, like burying the pipelines without referring to the existing guidelines and plan (Jaw & Hashim, 2014).

Even though, with the development in technology and research in this field, such as the various frequencies and numerical modelling, it gains the confidence level to validate the locational information subsurface utility without using much effort to explore the nearest mainhole for accuracy assessment during the conventional way of underground utility mapping. With such findings, the term of three-dimensional (3D) format can be provided with respect to the accurate as-built information, which can relate to the concept of digital earth (Jaw

& Hashim, 2014). In conclusion, all that information can help to avoid the accidental damage during the construction or excavation activity, improve the maintenance work and support the knowledgeable infrastructure planning (Gani & Hamid, 2018).

IV. METHOD OF GROUND PENETRATING RADAR DETECTION

GPR consists of four main elements like transmitting unit, the receiving unit, the control unit and the display unit. In addition, the various types of frequencies are used to determine the depth of penetration of underground utility and the resolution of the radargram that shows in the display unit will depend on the frequency (Nordin et al., 2022). According to the DSSM, the table of various types of frequency and depth penetration is represented in Table 1.0.

Table 1.0 Frequency and Depth (DSSM, 2007)

Sensor	Frequency	Depth
High Frequency	> 1000 MHz	< 0.5 m
Medium-high Frequency	400 – 600 MHz	0.5 m – 1.5 m
Medium-low Frequency	200 – 400 MHz	1.5 m – 2.0 m
Low Frequency	< 200 MHz	2.0 m – 3.0 m

By refer the table above, the suitable method that will be used in this research is using frequency 1000 MHz because the expected outcome of this study will bury the metal and pvc pipe only in the range of 0.4 – 0.5 m. Other than that, the UTSI Trivue GPR instrument that will be used in this study has three different types of frequency antenna including the 1000 MHz. For the soil types that will be used in this study, a combination of a random sample of soil will be used but in different conditions which are wet and dry. For dry soil, the sample of soil will be dried directly to the sun and for wet, the soil will add the amount of water that will make the texture and condition like a mud.

V. ROOT MEAN SQUARE ERROR

Root Mean Square Error (RMSE) is a statistical analysis that can be used in the accuracy assessment of GPR depth penetration data to determine accuracy and reliability. The concept in this analysis is to compare the actual depth value (leveling method) with the GPR depth that is produced by the radar reflection in underground space that is shown in the radargram. The equation for RMSE shows:

$$\textbf{RMSE} = \sqrt{[\ \Sigma(P_i - O_i)^2 / n]} \qquad 1.0$$

where Σ = fancy symbol that means "sum"
P_i = predicted value for the ith observation in the dataset
O_i = observed value for the ith observation in the dataset
n = sample size

The result from the comparison of actual depth and GPR depth will be classified into the numerical table to make the comparison easy to determine an analysis. The example of comparison table shows at Figure 1.0.

Type of Soil	Type of Pipe	Ground Level (m)	Pipe Underneath (m)	Depth (m)
Top Soil	PVC	9.357	9.843	**0.486**
	Iron Pipe	9.365	9.850	**0.485**
Silt Soil	PVC	9.364	9.855	**0.491**
	Iron Pipe	9.358	9.852	**0.494**
Fine Sand	PVC	9.325	9.871	**0.546**
	Iron Pipe	9.326	9.858	**0.532**

Figure 1.0 Example comparison table of actual depth with GPR depth (Hassan et al., 2023).

VI. RADARGRAM ENHANCEMENT

Radargram is a GPR image that is produced during the scanning process of the underground utility (David J. Daniels, 2004). The look and resolution of radargram data depend on the surface topography, soil moisture, clay content, and various other factors. The knowledge and skills are important in interpreting the data because

the radargram represented in the 2-D profiles makes it difficult to analyze the information from the image. The content in the radargram had subsurface properties that were scanned on the earth's surface before (Nordin et al., 2022).

Furthermore, image enhancement from GPR nowadays has several types of techniques, such as migration (Eyuboglu et al., 2014), non-linear processing (Chen & Jeng, 2011), wave equation redatuming (Liu et al., 2007), deep learning-based techniques (Besaw & Stimac, 2014), and seismic analysis (Fisher et al., 1996). All these techniques only have one main objective, which is to optimize the radargram image from the GPR instrument to get the best depth penetration value by their procedure and expected result. Based on the previous research that has been studied, a shortlist of the enhancement techniques, like migration, non-linear processing, and Hilbert transformation processing, the comparison table of Table 2.0 has been created to make the decision-making and analysis easier to relate to this research objective.

Table 2.0 Shortlist table for digital technique processing image for GPR

Types	**Migration**	**Non-linear processing**	**Hilbert Transformation**
Application	Utility Mapping and Geological	Utility Detection, Archaelogy and Environmental studies.	Utility detection, Water Leakage, Subsurfaces Features
Function	• Hyperolic reflection correction • Enhanced depth accuracy • Deffraction suppression • Improve resolution	• Noise reduction • Signal enhancement • Distortion correction • Inreased depth penetration.	• Generate analytic signal • Inreaces image resolution
Limitation	• High computational demand • Noise sensitivity, limited accuracy with complex subsurfaces • Need accurate velocity model.	• High computational demand • Time-consuming • Complexity in parameter selection	• Need specific pratical • Sensitive to the noise • Misleading enhancement.

By referring the Table 2.0, all the techniques can provide good results and achieve the objective of this research which is to propose the best practice to enhance the accuracy and quality of depth on radargram images of wet and soil conditions. However, the limitation needs to be considered which is the reliability of the instrument, time, software and level of study. After the analysis and observation of all the aspects to achieve the expected outcome and fulfill the objective, the migration is near with research focus with the combination of the other techniques is the best decision to achieve the best practice during the radargram enhancement. Other than that, this decision-making is chosen by referring to the previous study from Eyuboglu et al., (2014) and Hassan et al., (2023) that used the combination of digital processing techniques to achieve their research objective in great ways.

VII. DATA PROCESSING SOFTWARE (REFLEX-W SOFTWARE)

The software that is used in this research is Reflex-W from Sandmeier Software. This software is a geophysical software program that allows users to process and interpret signal data in 2D and 3D. This software gives the user are advantage of easily importing and exporting the data from several formats and is already compatible with various types of GPR systems such as GSSI, RAMAC, Pulse-EKKO, UTSI and others. The selection for this software depends on the accessibility at the undergraduate level which is already provided by the Science Survey and Geomatics including the GPR instrument. Figure 2.0 shows the post-processing flowchart in the Reflex-W Software.

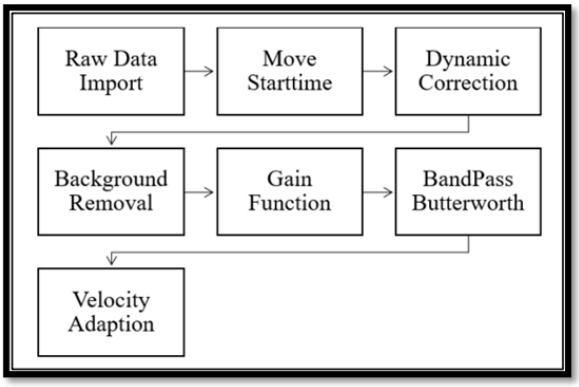


Figure 2.0 Flowchart of post-processing in ReflexW (Hassan et al., 2023).

VIII. METHODOLOGY

This chapter consists of several parts starting with the preliminary study, instrument calibration, data collection, data processing and ending with the summary for this chapter. The general flowchart for this chapter is shown in Figure 3.0 to make sure this methodology becomes smooth and efficient to achieve the objectives.

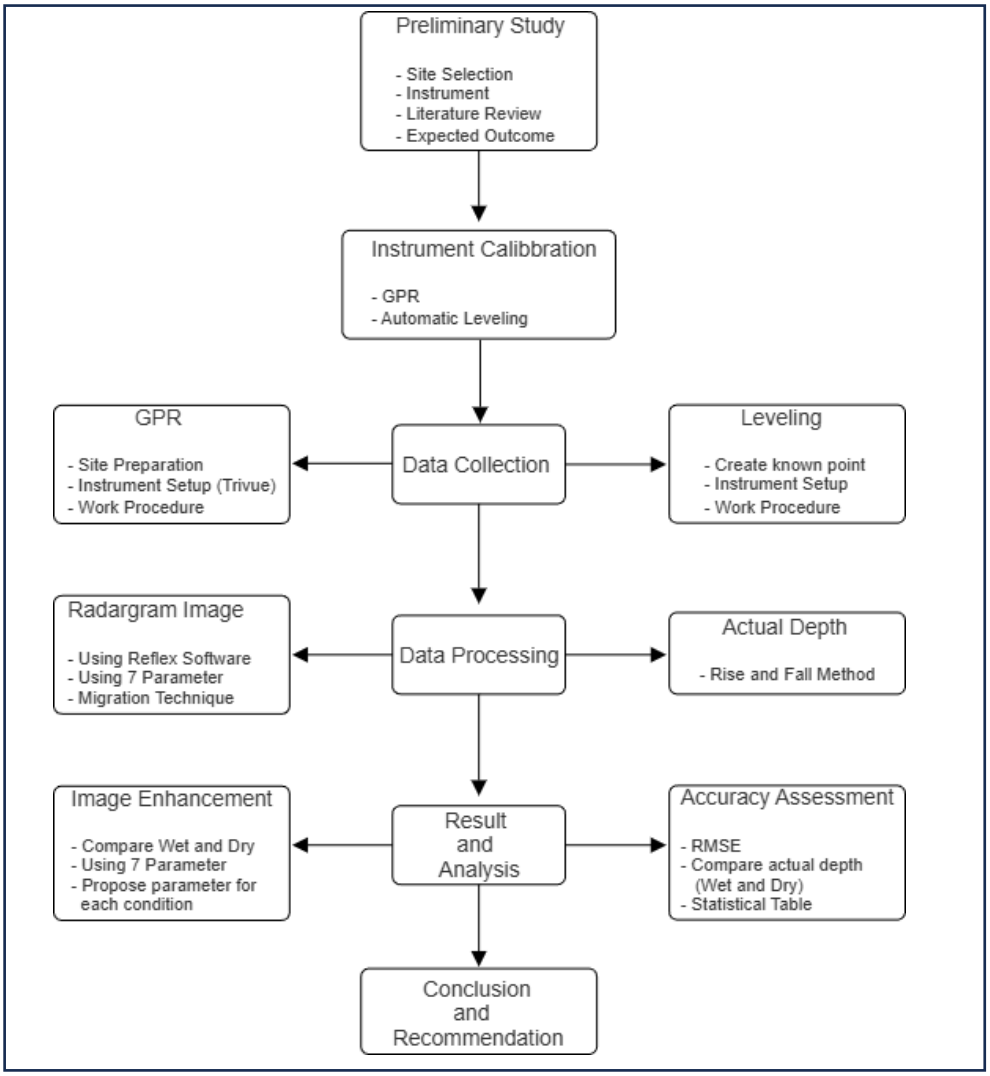


Figure 3.0 General research methodology flowchart

The realization of the configuration on this methodology is shown in Figure 4.0. The plywood is used to separate the boundary of each soil situation, the metal pipe and PVC pipe will be attached to the plywood and then fill all two spaces with different soil condition.

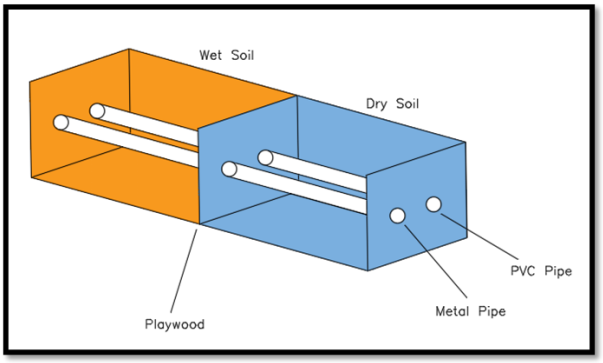


Figure 4.0 3D site customization

For GPR data collection, UTSI Trivue GPR will be used in this thesis because of its capabilities and accessibility, which can give an advantage to this study. This GPR detection will be conducted on two different types of soil, wet and dry, using the same random type of soil. The GPR detection will use the Two-Way Travel Time (TWT) method that transmits the signal through the subsurfaces and receives the reflected signal using a receiver. The suitable frequency used in this study is 1 GHz because the customization of both pipes is below 0.5 meters.

During the data collection, GPR will be detecting the utilities object at one hole that has metal and PVC pipes. The distance of metal and PVC pipes is 0.4 meters, and the length of the hole is 1.5 meters. The hole will be separated to become two compartments for dry and wet soil using the plywood with both pipes attached to the plywood with the same depth as the example in Figure 5.0. The data will collect three different value of permittivity which is 8 as a default, 10 for the dry and 20 for the wet conditions.

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Figure 5.0 The plywood uses for as boundaries for each soil condition (Hassan et al., 2023).

The GPR instrument will detect the pipes perpendicular to the holes in two soil conditions, repeated 15 times for each condition as shown in Figure 6.0. This repetition is to check the consistency of GPR detection and ensure accurate depth penetration for each soil situation. All the data measured by the GPR for each situation and each repetition will be recorded on the tablet display and noted in a notebook for further processing.

Levelling data collection is a key component of the accuracy assessment that compares the depth accuracy of GPR measurements with conventional methods. This levelling process involves collecting the elevation values of the pipes before and after excavation. The values recorded before and after burial will be used to calculate the true depth of the pipes in the hole and compared with the GPR derived depth during the post-processing stage. This method begins with a known reference point, such as a Benchmark (BM) or Temporary Benchmark (TBM), following Circular No. 7 (2021) by DSSM. In this study, one point will be established near the site to serve as a known point (assumed value) for starting the levelling transfer. The procedure will be repeated twice to cover the two target points before and after pipe burial. Data will then undergo post-processing using rise and fall calculations to reduce and check allowable tolerance levels.

The actual data collected through the leveling method will be compared with the GPR data using the RMSE statistical model to determine the accuracy of pipe detection under different pipe materials and soil conditions. The results will be presented in a line graph for depth comparison of different pipe materials and a bar graph for accuracy comparisons based on pipe material and soil type. These results will aid understanding during the analysis section and will be further supported by tabular data. Examples of the expected outcomes are shown in Figures 7.0 and 8.0.

Once the GPR data collection is complete, it will be processed using specialized software such as ReflexW. Radargram images which contain crucial depth information can be analyzed in both 2D and 3D formats using ReflexW. In this research, the migration technique will be used to enhance radargram images, along with several other methods such as move start-time, dynamic correction, background removal, gain function and Butterworth bandpass filtering. The raw radargram data from GPR observations will be processed in 2D using ReflexW software. The processing steps are illustrated in Figure 2.0, showing the seven radargram processing parameters based on a previous study by (Hassan et al., 2023). The software interface is highly functional for importing, processing, and analyzing radargram images.

Additionally, specific parameters for different soil types can be categorized after filtering and editing the data using this software. The entire processing workflow can be saved using the sequence processing function in ReflexW. An example of this function is shown in Figure 6.0. This feature is particularly useful for creating a standardized guideline for image enhancement as it allows the process to be recorded and reused.

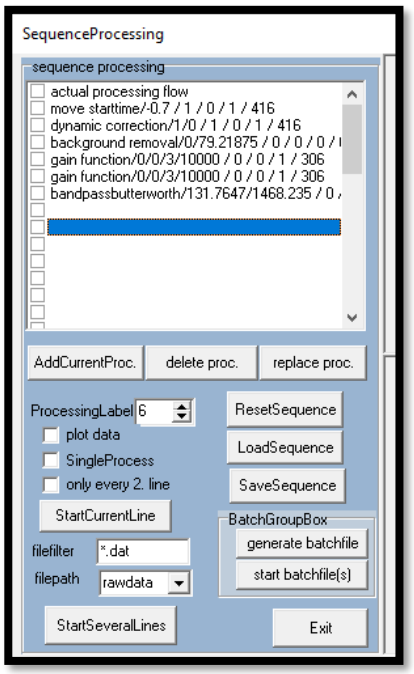


Figure 6.0 The sequence processing function in ReflexW Software

IX. EXPECTED OUTCOME

The expected outcomes of this research are divided into two main outputs which is accuracy assessment presented in a bar graph and a guideline for image enhancement. Figure 7.0 displays a line graph that illustrates an example of depth comparison, while Figure 8.0 presents a bar graph representing the accuracy assessment of different pipe types and soil conditions using Root Mean Square Error (RMSE) values.

The second output includes two key points. Point one outlines the best practices for wet soil conditions and point two covers best practices for dry soil conditions. These practices involve enhancement techniques that can be applied to maximize the clarity of radargram images obtained from GPR, ultimately helping to determine depth accuracy more effectively. This output aims to improve image quality in wet environments and define an expected range of accuracy, offering valuable guidance for surveyors or geologists. It will also increase their confidence when making decisions during subsurface detection surveys using Ground Penetrating Radar.

a) OUTPUT 1

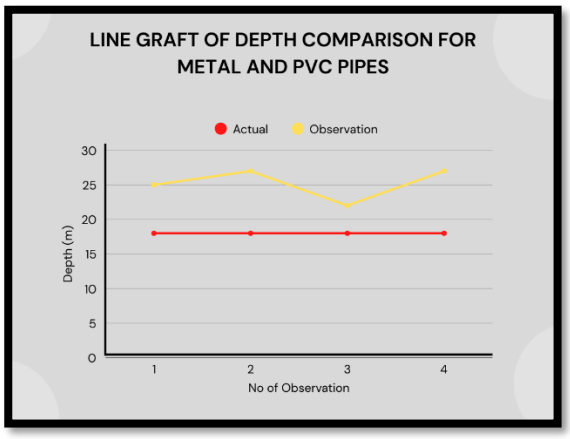


Figure 7.0 Example of Line Graft for depth comparison

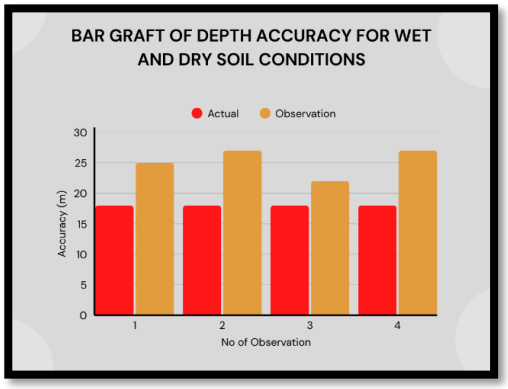


Figure 8.0 Example of Bar Graft for depth accuracy comparison

b) OUTPUT 2

1. Practice for Wet Soil Condition

Description: Conduct to enhance processing to make the hiperbola more clear
Importance: Make sure the radargram image does not have any distortion (undetected image)
Best Practice:

- Use 7 parameter
- Using migration technique

Avoid: The raw image must in the 15-20 permittivity value.

2. Practice for Dry Soil Condition

Description: Conduct to enhance processing to make the hiperbola more clear
Importance: Make sure the radargram image does not have any distortion (undetected image)
Best Practice:

- Use 7 parameter

Avoid: The raw image must in the 10-permittivity value.

CONCLUSION

This paper aims to evaluate the accuracy of the GPR instrument in both wet and dry soil conditions and propose best practices for GPR operators to maximize functionality and achieve more accurate depth results in utility detection work. Additionally, it seeks to enhance data processing techniques related to radargram imaging using ReflexW software, particularly for wet soil conditions. Moreover, the migration technique applied during radargram enhancement has been shown to improve the accuracy of pipe depth detection in wet soil conditions, as supported by a previous study by Eyuboglu et al. (2014).

Furthermore, given the rapid advancement of technology today, studies on GPR usage are highly necessary due to the diverse types of buried utilities, such as PVC and metal pipes, found in various soil conditions. These variations present challenges for GPR operators in making accurate decisions, potentially leading to significant risks in ongoing engineering projects, such as building construction, road widening, and other infrastructure developments. The final outcome of this study will provide a parameter table for depth comparison and image enhancement settings, making it easier for GPR operators to understand and apply best practices effectively.

ACKNOWLEDGMENT

I would like to sincerely thank the Department of Building Surveying, UiTM Perak Branch, for giving me the opportunity to participate in this conference and for their continuous support throughout my research. A special thanks to my supervisor, Sr. Mohamad Hezri Razali, for his valuable guidance, constructive feedback, and encouragement, which have greatly contributed to the success of this study. Her expertise and patience have been essential in shaping my research and analysis. I am also very grateful to the experts who provided feedback, as their insights were crucial to completing this research.

Lastly, I want to express my heartfelt appreciation to my family and friends for their support and motivation throughout this journey. I also recognize my own perseverance and dedication in overcoming challenges along the way.

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IMPLEMENTATION OF VALUE ENGINEERING IN ENHANCING COST EFFICIENCY AND FUNCTIONALITY OF AUTONOMOUS RAPID TRANSIT (ART) PROJECTS IN MALAYSIA

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ABSTRACT

The rapid urbanization of Malaysia has increased traffic congestion, highlighting the need for sustainable public transportation solutions. Autonomous Rapid Transit (ART) offers a flexible and cost-effective alternative to traditional rail-based transit. However, its implementation faces significant challenges, including high initial costs, integration complexities and reliance on advanced technology. Despite ART's success in other countries, research on optimizing its adoption in Malaysia remains limited, particularly regarding the role of Value Engineering (VE) in improving cost efficiency and functionality. This research aims to develop a VE strategy for overcoming high life cycle cost of ART systems to enhance cost efficiency and functionality of ART projects in Malaysia. In order to achieve the aim of this research, a mixed-method approach incorporating literature review, questionnaire surveys and interviews with industry professionals is adopted to analyze the challenges of ART implementation, compare VE with conventional cost management approaches and propose a VE-driven strategy to optimise life-cycle costs while enhancing operational effectiveness. The research highlights that VE can significantly reduce costs by optimizing material selection, refining design methodologies and improving project execution processes. Compared to traditional cost management, VE fosters long-term financial sustainability and operational effectiveness, addressing ART's high capital investment and maintenance expenses. This research contributes to the growing body of knowledge on sustainable transit infrastructure and provides insights for policymakers and urban planners on the feasibility of ART in Malaysia. By integrating VE into transit planning, Malaysia can enhance the economic viability of ART projects while ensuring environmentally sustainable and high-functioning urban transportation systems.

Keywords: Autonomous Rapid Transit, Value Engineering, Conventional Cost Management

I. INTRODUCTION

According to the Department of Statistics Malaysia, Malaysia's rapid urbanization with its urban population increasing from 28.4% in 1970 to 75.1% in 2020 has intensified the need for sustainable and efficient public transportation solutions. As cities grow, the dependence on private vehicles has led to chronic traffic congestion, environmental degradation and increased infrastructure strain. In response, Autonomous Rapid Transit (ART) emerges as a cutting-edge transportation system that blends the high capacity of light rail with the flexibility and cost-efficiency of buses. Unlike conventional rail systems, ART operates on virtual tracks and does not require steel rails, offering an innovative alternative for cities constrained by limited space and funding.

Autonomous Rapid Transit (ART), also known as a trackless tram, is an emerging mode of urban transportation that combines the benefits of bus rapid transit and light rail. It operates using advanced driver-assistance systems, sensors and dedicated virtual tracks that enable the ART vehicles to move autonomously along pre-defined routes (Feng et al., 2024). The flexibility of ART allows cities to bypass the need for costly rail infrastructure, making it ideal for rapidly urbanizing regions like Malaysia, where budget constraints and limited urban space pose significant planning challenges.

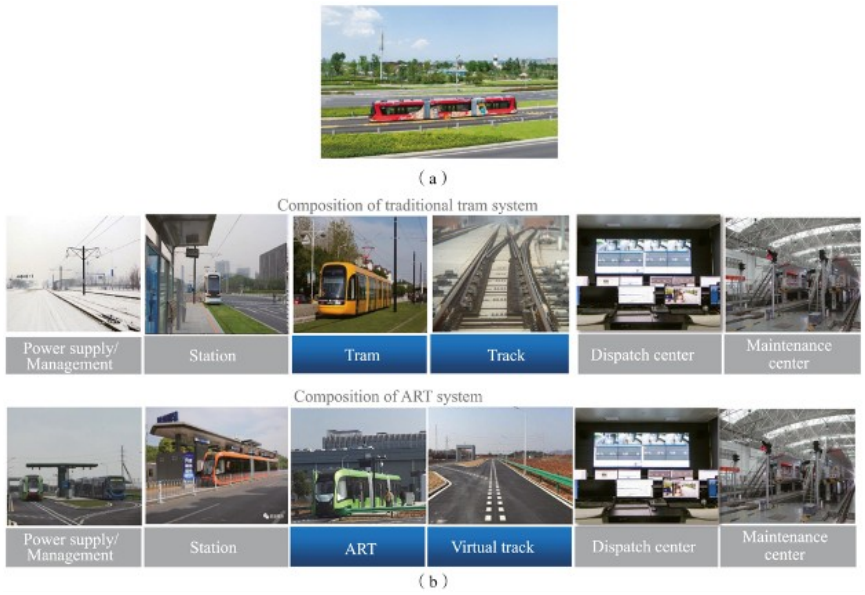


Figure 1.0 Comparison Between ART system and traditional tram system

II. PROBLEM STATEMENT

Despite the advantages of ART systems such as scalability, lower emissions and route flexibility, the implementation process is not without significant hurdles. In Malaysia, the high initial capital investment needed for ART infrastructure remains a major barrier. This includes the construction of ART stations, command centers, vehicle acquisition and the development of ART-exclusive lanes. Additionally, ART relies on sophisticated technologies like LiDAR, radar, GPS and AI-based navigation systems that require routine maintenance, calibration and continuous upgrading to ensure accurate functioning, especially in challenging weather conditions like heavy rain or fog that can impact sensor accuracy (Reutebuch et al., 2015). Additionally, ART systems are connected to centralized servers and digital networks, making them very likely to face cyber-attacks, so ongoing cybersecurity monitoring is essential, which leads to high maintenance and operating cost.

Public acceptance and trust are also critical to successful ART implementation. Given that ART is still a novel concept in Malaysia, the general public and even some stakeholders may be skeptical about its reliability, safety and operational efficiency. Lessons from international case studies such as those in Mexico and Qatar highlight the importance of extensive public awareness campaigns, transparent feasibility studies and stakeholder engagement to ensure smooth implementation. Without these, the ART system risks facing public backlash, underutilization, or even project cancellation in the worst case scenario. However, on the other hand, if the ART project is handled with care and can be successfully implemented, it definitely will bring a lot of benefits to Malaysia.

Another concern relates to ART's integration into Malaysia's existing urban infrastructure. It is because large-scale construction projects are less likely possible in urban areas due to space constraints and long existing transportation networks which can cause short term and long-term disruptions. A real case in Paris, similar challenges have been encountered when tram systems expanded across the city. It was necessary to relocate the bus stops, restructure roadways and change traffic patterns in order to adapt to the new tram systems in Paris (Debrincat & Meret-Conti, 2016). Another notable example is the construction of Klang Valley Mass Rapid Transit (KVMRT), in which the mode is similar to the ART systems. It aims to improve connectivity across Kuala Lumpur, but construction of tunnels in urban areas like Bukit Bintang is a significant integration challenge as the city already has complex networks of roads and public transport systems. Retrofitting these networks to accommodate ART without causing major disruptions requires meticulous planning and strategic investment. In addition to technical complexities, issues related to land acquisition, traffic management during construction and environmental impact assessments must also be addressed to minimize long-term negative effects.

To overcome these multifaceted challenges, the application of Value Engineering (VE) is proposed as a strategic approach. VE is a structured and systematic methodology aimed at enhancing the value of a product, project or process by optimizing its functions and minimizing unnecessary costs (Zhao et al., 2024). In the context of ART, VE involves analyzing the key functional elements of ART systems and exploring alternative solutions that reduce costs while maintaining or improving performance and safety standards (Kumar et al., 2024). Unlike traditional cost-cutting measures, VE emphasizes function over form and encourages

interdisciplinary collaboration. In contrast, conventional cost management follows established practices and standards. It focuses on incremental cost control rather than creative problem-solving (Mulley & Nelson, 2021). The approach ensures that all resources are utilized efficiently, but it does not actively encourage rethinking project design or processes.

III. METHODOLOGY

This paper adopts a mixed-methods approach to investigate the role of value engineering in ART projects. In order to give a thorough understanding of how value engineering principles can be used to improve functionality and cost effectiveness in ART projects, the approach is utilized to gather and examine both qualitative and quantitative data. The study combines primary data collection via case studies and online questionnaires with secondary data collection via literature review.

It begins with literature review to form the foundation of this research by identifying existing knowledge and best practices related to value engineering in infrastructure projects. To learn how value engineering is possible to lower costs without sacrificing performance, relevant academic journals and government publications will be reviewed. The fundamentals of value engineering, its use in ART systems and its effect on project efficiency are important areas to focus. The study offers a theoretical foundation for the main stages of data gathering and analysis while also examining the challenges encountered with integrating value engineering in ART systems.

In order to obtain useful insights, this research uses both questionnaire survey and interview. An online questionnaire is conducted to gather quantitative data from the targeted respondents, who play a vital role in the value engineering process. The survey aims to understand their perspectives and responsibilities in implementing value engineering in ART projects. Participants are selected from professionals with experience in infrastructure projects, ensuring the findings' relevance and application. Besides that, interviews with industry experts will be conducted to get in-depth information regarding the ART system.

IV. LITERATURE REVIEW

The rapid urbanization of modern cities has necessitated innovative transportation solutions to address challenges like congestion, environmental degradation and accessibility. Autonomous Rapid Transit (ART) systems have emerged as a transformative approach to urban mobility, leveraging automation and advanced technologies to redefine public transportation. By combining efficiency, sustainability and reliability, ART systems offer a promising alternative to traditional modes of transit. The implementation of ART systems undoubtedly brings a lot of benefits not only to the country, but to the passengers who utilize it as well.

ART systems operate with precision, offering higher frequency and reliability compared to traditional public transit. By automating operations, ART systems can dynamically adjust schedules and routes to reduce congestion during peak hours. Studies highlight that these systems improve accessibility and reduce delays, contributing to a smoother urban traffic flow (Frank & Jonathan, 2024). ART systems leverage advanced sensors and AI for real-time decision-making which minimizes human error. The Copenhagen Cityringen metro, an example of a fully automated, driverless underground metro line that loops through central Copenhagen and Frederiksberg, has been credited with enhancing passenger safety and ensuring consistent service quality (Berlato, 2024).

On a different point of view, automation in transit systems lowers operational costs by reducing reliance on human labor for repetitive tasks such as driving and ticketing. Research by Gusev and Gilroy (2024) points out that autonomous transport systems decrease long-term maintenance and energy costs, making public transport more affordable for both operators and passengers. ART systems utilize big data to monitor and optimize operations. This capability enables efficient route planning, predictive maintenance and rapid response to disruptions as demonstrated in studies on integrated AI and autonomous transit networks (Thawainin et al., 2024).

Table 1.0 Comparison Between Value Engineering and Conventional Cost Management

Aspect	Value Engineering	Conventional Cost Management
Objective	To improve the value of a product or process by balancing functionality and cost	To control and reduce costs effectively for project financial accountability
Focus	Emphasis on enhancing value by optimizing the relationship between function and cost	Emphasis on cost reduction and control without detailed analysis of value
Methodology	Systematic, creative problem-solving process to enhance product value	Analytical and accounting driven techniques for budget adherence

Key Features	Function Analysis System Technique (FAST) to brainstorm alternative solutions and evaluate effectiveness	Variance Analysis which aids in budgeting, cost estimation and expense tracking
Outcome	Achieving cost reduction without compromising quality or functionality	Reduce expenditures and minimize risk of cost overruns
Innovation	Promotes innovation through creative thinking and re-evaluating product functions	Rarely focuses on innovation as it only prioritizes adherence to financial constraints

One of the primary advantages of value engineering is cost optimization. By analyzing design processes and identifying unnecessary expenses, value engineering ensures that transit systems are built and maintained within budget constraints. For example, Zhao (2024) highlights that in intelligent transportation projects, value engineering methods can optimize resource use by reducing redundant systems and improving integration across components to reduce construction and operational costs. Furthermore, the methodology accounts for life- cycle costs such as maintenance and energy use, which are critical for long term economic viability in transit systems.

Advanced transit systems often involve the use of cutting-edge technologies including automated ticketing, real time tracking and intelligent routing systems. Value engineering facilitates the seamless integration of these technologies by prioritizing functionality over extra features. Zhao (2024) highlights how value-focused strategies can help transit authorities invest in AI and other innovative tools that improve service reliability and accessibility while reducing costs. The implementation of value engineering in advanced transit systems offers a comprehensive framework for achieving economic efficiency, enhanced functionality and sustainability. By promoting innovation and collaboration, value engineering not only addresses immediate project goals but also aligns with broader urban development and sustainability objectives.

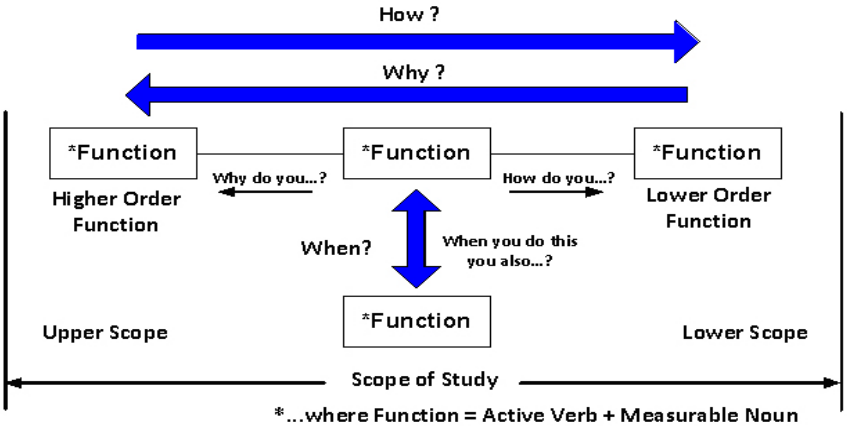


Figure 2.0 FAST Diagram

The Function Analysis System Technique (FAST) is a vital engineering technique for systematically identifying, analyzing and prioritizing functions inside a product, process or system. FAST encourages innovative problem-solving and ensures that resources are directed toward functions that genuinely bring value by focusing on what a function delivers and why it is required. The method uses the FAST diagram, a structured diagram that shows the relationships between functions in a hierarchical "how-why" framework (Miles, 1972). In the context of advanced transit systems, FAST enables a systematic breakdown of complex systems into their core functions, helping to identify inefficiencies and reduce costs. It is beneficial in urban transit, where optimizing service delivery and resource allocation is crucial to meet the growing demand for efficient transportation.

This paper aims to investigate the application of value engineering as a transformative tool to enhance cost efficiency and functionality in ART projects in Malaysia. It examines the challenges involved in ART implementation, draws comparisons between VE and conventional cost management approaches and proposes a tailored VE strategy to mitigate high life cycle costs. Through a combination of literature review, quantitative data analysis and expert interviews, the research provides insights that contribute to developing more sustainable and cost-effective public transportation systems in Malaysia. Furthermore, this research contributes to the broader discourse on sustainable urban development in Southeast Asia by aligning its objectives with the United Nations Sustainable Development Goals (SDGs), particularly Goal 9 (Industry, Innovation and Infrastructure) and Goal 11 (Sustainable Cities and Communities). It also supports the aspirations of Malaysia's New Industrial Master Plan (NIMP) 2030, which emphasizes smart mobility solutions, green technology integration, and infrastructure resilience.

Ultimately, the integration of value engineering into Malaysia's ART projects holds the potential to redefine how transportation infrastructure is designed and delivered in the country. By focusing on functionality and long-term sustainability, VE can serve as a catalyst for innovation and strategic planning in the construction and transportation sectors. This research seeks to provide a foundational framework for decision-makers, planners and all the experts in the construction industry to incorporate VE principles into future ART initiatives, ensuring their success and scalability across Malaysia.

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LENTICULAR CARTOGRAPHY: ENHANCING HISTORICAL PERSPECTIVE THROUGH INTERATIVE MAP VISUALIZATION

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ABSTRACT

Lenticular cartography is a new technique that combines printing and historical map technology to enhance spatial-temporal visualization. This study aims to explore the effectiveness of lenticular visualization techniques in interpreting historical maps that allow users to see changes over time in an interactive display. This research uses a combination of historical data acquisition, cartographic processing and lenticular printing techniques. Historical maps from different time periods are collected, analysed and displayed in a dynamic map. Image processing software is used to align and merge multiple layers into a lenticular format. The effectiveness of lenticular cartography is evaluated through comparative analysis and user testing, focusing on their level of spatial understanding and engagement. Preliminary findings show that lenticular cartography significantly enhances users' understanding of historical transformations by providing dynamic map transitions between time periods. Compared to static historical maps, lenticular visualization enhances spatial awareness and engagement. However, challenges such as image alignment accuracy, data accuracy and printing limitations affect the quality of visualization. Despite these challenges, users have shown a greater ability to view and analyse historical change with lenticular maps than with conventional methods. Lenticular cartography presents a new approach to historical map visualization, offering an interactive and immersive experience that aids in understanding spatial and temporal change. This study contributes to cartographic visualization by demonstrating the potential of lenticular technology in researching the historical understanding of a place. Future research focuses on optimizing printing techniques, improving multi-layered images, and exploring dynamic maps in educational contexts, bringing new value to the world of cartography.

Keywords: Lenticular Cartography, Historical Maps, Interactive Visualization, Spatial-Temporal Analysis, Cartography, Map.

I . INTRODUCTION

A. Background Study

Development in the world of optical visual arts has led to the lenticular world. The emergence of the lenticular world has been seen as a transformative force across multiple domains, especially in the fields of advertising and design, where optical visual arts are captured through dynamic imagery. In the 17th century, G.A. Bois-Clair introduced innovations that adjusted images based on the perspective of the viewer's eye called "turning pictures" (Smith, 2010). Advances in lenticular technology have been shown to society, resulting in a deeper understanding of visual perception. This understanding is the beginning of all the basic concepts, namely, when the angle changes, the image appears to change, which prioritize human involvement and genuine human creativity without relying solely on automatic processes (Johnson & Lee, 2018).

Century after century, the development of lenticular technology in imaging has grown significantly. In the 20th century the emergence of digital technology has taken over the human role in the world of technology, making it more accessible and versatile. Software advancements allow designers to design easily to create more complex images, allowing for a more understandable and visually rich experience (Doe, 2021)

In the advertising world, lenticular printing is widely used, on eye-catching billboards, and product displays that make products stand out with 3D effects or animations. The use of lenticular technology is used more widely and beneficially in the world of education were. Lenticular technology is used in the production of maps and historical images depict layered information depicted in the form of static format (Brown, 2019).

B. Problem Statement

In the world of mapmaking, the public is often presented with static maps that present limitations in conveying complex and dynamic information, leading to a shallow understanding of critical geographic narratives among users. The need for innovative mapping solutions has become increasingly apparent, especially as educational and environmental institutions strive to foster deeper engagement with content. Lenticular mapping technology offers an engaging alternative by allowing users to explore multiple perspective or timelines through an interactive visual medium.

Although the emergence of digital interactive maps provides enhanced capabilities, most of these solution come with constraints related to accessibility and technological infrastructure. This clearly demonstrated in many learning environments where resources and equipment are relatively limited.

Currently, research exploring the effectiveness of lenticular mapping as an educational tool in history and environmental contexts is limited. Empirical studies evaluating the impact of lenticular maps on user engagement, understanding and retention compared to traditional and digital mapping methods are scarce.

C. Aim and objective

The primary aim of this project is to develop and evaluate lenticular maps to improve the visualization of historical changes and geographical evolution, offering users an interactive experience that enhances their understanding of historical data.

D. Geographical Focus and Its Relevance

Uitm Shah Alam is an ideal location for this study due to several key reasons:

a) Rich Historical Data: The university has maintained a comprehensive archive of its history, including campus maps, photographs and architectural plans, making it a rich source of historical data for this research

b) Impact of Urbanization: As a major educational institution, UiTM has played a significant role in the development of Shah Alam. The campus's growth reflects broader trends in urban planning and infrastructure development in Klang Valley.

c) Educational and Cultural Relevance: The evolution of UiTM Shah Alam offers valuable insights into how educational institutions adapt to changing needs and growing populations. The university's historical significance in Malaysia's educational landscape further underscores its importance as study area.

II. LITERATURE REVIEW

A. Historical

Lenticular technology, which creates images with depth or motion effects through layered lenses and printed images, has origin dated back to the 16th century. Early visual experiments, known as "tabula scalata" or "turning pictures" demonstrated an initial form of lenticular imagery by representing different images depending on the viewing angle (Gombrich,1982; Luckiesh,1922)

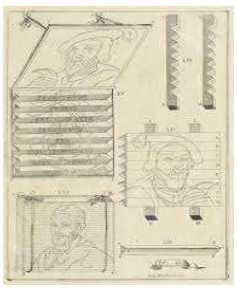


Figure 1.0 Diagram of Tabula Scala Concept

These early primarily served as artistic curiosities, engaging viewers with simple transformations or dual images. The 20th century saw significant advancements in lenticular technology, especially in the field of advertising items. For instance, Vari-Vue, a prominent company in the 1930s, popularized lenticular images for use political campaigns and children's merchandise, embedding animation or flip effects into badges and

trading cards (Crary,1992; Wade, 2009).

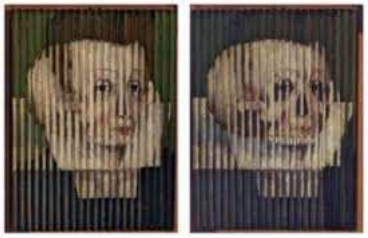


Figure 2.0 Diagram of Flip Effects

With advancements in lens design and printing technology, lenticular images became more complex and accessible. The development of cylindrical lenses in particular enabled more detailed 3D and motion effects, which found new applications in marketing and educational tools (Wade & Finger, 2001; Lefebvre & Seron, 2009).

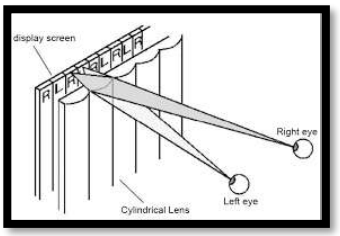


Figure 3.0 Diagram of Cylindrical Lens

By late 20th century, lenticular technology was not only used for entertainment but also in functional context, such as educational displays and public information signage. The evolution of digital printing has further enhanced the precision and quality of lenticular images, allowing for high definition visuals that maintain clarity across multiple angles (Lefebvre & Seron, 2009).

B. Research Gap

a) Static Map Representation
Most historical maps are presented in static formats which do not effectively communicate temporal changes.

b) Limited Public Engagement
Traditional cartography outputs, such as GIS visualizations, tend to be academic or technical.

c) Technological Limitations
Although augmented and digital cartography is evolving, there's limited use of interactive or dynamic media to enhance spatial storytelling

Previous studies in historical cartography have largely focused on static or digital GIS-based representations of spatial change (Harley, 1989; Goodchild, 2007). These methods, while effective in scholarly contexts, often fail to provide intuitive, comparative visualizations that engage wider audiences, particularly when representing changes over time. Traditional methods such as side-by-side historical and modern maps or digital overlays require a certain level of technical literacy and do not fully utilize tactile or analog interaction methods (Caquard & Cartwright, 2014).

This research addresses the gap by introducing a lenticular cartography approach that combine historical and contemporary map layers into a single physical medium. The method leverages lenticular lenses to allow viewers to perceive transitions between different temporal states of a map based on viewing angle. This fills mapping remains largely unexplored.

C. Lenticular Lens

Lenticular lenses are the fundamental component of lenticular technology, consisting of multiple small, convex lenses aligned in parallel. These lenses work by manipulating the path of light rays through refraction, creating the illusion of depth, motion, or multiple perspectives within a single image. The most common types of lenticular lenses used in printing are cylindrical lenses, which bend light in such a way that the viewer perceives different images depending on their viewing angle. This effect is similar to how the human eye perceives depth

through stereopsis, except that lenticular lenses simulate this effect artificially by controlling the light that enters the viewer's eyes (Lefebvre & Seron, 2009).

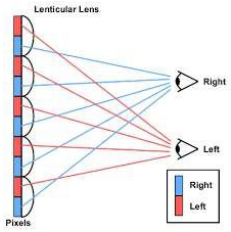


Figure 4.0 Diagram of Fundamental of Lenticular Lens

Lenticular lenses come in various configurations, such as micro-lenses or larger cylindrical lenses, to produce different visual effects. The size and curvature of the lens determine the viewing angle and the clarity of the images presented. In more advanced forms, such as those used for 3D effects, the lenses may be designed to provide a wider field of view, offering a more immersive experience. By combining these lenses with high-quality printing techniques, lenticular technology is able to display complex images that change in real time as the viewer shifts their perspective (Lefebvre & Seron, 2009).

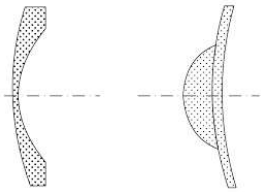


Figure 5.0 Diagram of Convex Lens

One of the key challenges with lenticular lenses is achieving precise alignment between the printed image and the lenses. Small deviations in alignment can result in misalignment between the multiple images, leading to a distorted or unclear visual experience. As lenticular printing technology has advanced, solutions have been developed to automate the alignment process, allowing for more accurate and higher- quality lenticular images. These advancements have made lenticular prints not only more effective in displaying dynamic images but also more accessible for commercial and educational applications (Wade & Finger, 2001).

The interaction between lenticular lenses and printed images enables the display of multiple images or a sequence of images that appear to change depending on the viewer's position. This ability to display dynamic content without requiring digital devices makes lenticular lenses a versatile tool for applications that demand high- quality visual presentation, such as advertising, packaging, and even geographic maps (Lefebvre & Seron, 2009).

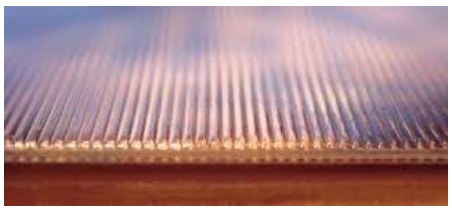


Figure 6.0 Diagram of Example of Lenticular Material

D. Lenticular Printing

Lenticular printing is a specialized technique that integrates lenticular lenses with printed images to create dynamic, multi-layered visuals. The process begins with the creation of digital images, which are then interlaced—essentially combining multiple images into a single file that can be displayed through the lenticular lens. Software plays a critical role in this process by enabling the manipulation and alignment of images in a way that ensures the correct visual effect is achieved when viewed through the lenticular lens (Lefebvre & Seron, 2009). Modern software solutions allow for more precise control over the interlacing process, enhancing the overall quality of lenticular prints and minimizing issues like image misalignment.

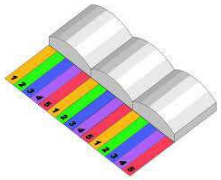


Figure 7.0 Diagram of How Printing Works

In addition to interlacing software, digital printing technology has advanced to the point where high-resolution lenticular prints can be produced with greater ease. The advent of high-definition digital printers allows for the accurate rendering of images in the fine detail required for lenticular technology. This has led to improvements in both the quality and versatility of lenticular prints, enabling them to be used for a wider range of applications, including geographic mapping and educational tools (Smith, 2002). The ability to print high-quality lenticular images at scale has made technology more viable for commercial use, especially for applications that require vivid, dynamic visuals.

While lenticular printing software and digital printing technologies have advanced significantly, challenges remain, particularly in terms of production costs and equipment requirements. High-quality lenticular printing requires specialized printers and lenses, which can make it expensive, particularly for smaller-scale projects. Nevertheless, as technology continues to evolve, it is expected that these costs will decrease, making lenticular printing more accessible for a broader range of uses, from educational applications to interactive maps and advertisements (Smith, 2002).

E. Lenticular Effects

Lenticular technology is capable of producing a variety of visual effects, each of which has unique applications. One of the primary lenticular effects is the transforming print effect, where two or more images are displayed in such a way that they appear to shift based on the viewer's perspective. This effect is commonly used in advertising and marketing materials, where the goal is to catch the viewer's attention with an image that seems to change or "flip" as they move around it. The shifting images, depending on the angle from which they are viewed, make the content appear dynamic, enhancing engagement and providing a more memorable visual experience (Lefebvre & Seron, 2009).

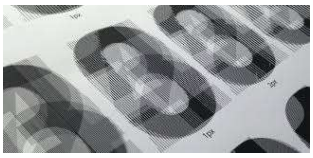


Figure 8.0 Diagram of Flip Effects

Another popular lenticular effect is the animated print, which is used to simulate motion. This effect involves a sequence of images that, when viewed from different angles, appear to animate in a way similar to a flipbook or stop-motion animation. Animated lenticular prints are widely used in product packaging, promotional materials, and even in educational displays where motion is needed to explain processes or sequences. The movement of the images appears smooth and continuous, providing an interactive visual experience that can be particularly engaging for younger audiences or students (Lefebvre & Seron, 2009; Smith, 2002).



Figure 9.0 Diagram of Animation Effects

The stereoscopic effect is another prominent lenticular application, where images appear to have depth without the need for 3D glasses. This effect is achieved by slightly altering the images seen by each eye, creating the illusion of depth through the lenses. Stereoscopic lenticular prints are used in various fields, including geographic mapping and medical imaging, where accurate visual representation of three-dimensional data is critical. By allowing viewers to perceive depth and volume in images, stereoscopic

lenticular prints can make complex data more comprehensible, aiding in fields where spatial understanding is important (Smith, 2002; Howard & Rogers, 2002).

III. METHODOLOGY

A. Flowchart methodology



Figure 10.0 Flowchart methodology

B. Data Collection

The Data Collection section serves as the foundation for building lenticular maps. This process involved identifying, sourcing, and preparing both historical and user data, utilizing advanced tools and technologies to ensure the accuracy, relevance, and usability of the collected data.

1) Historical Data Sources

Historical data for this study was gathered from various reliable sources to ensure comprehensive coverage of the targeted historical period of 1999. The historical data for this study, specifically focusing on the year 1999, will be obtained directly from a lecturer at UiTM Shah Alam, who has access to reliable and relevant archival materials. This data is expected to include maps and records that provide a clear representation of spatial and temporal conditions during the specified period. These sources include:

a) Printed Cartographic Collections: Physical maps and documents were accessed and digitized from the collections at UiTM Shah Alam. These resources were critical in understanding spatial changes and developments during 1999.

2) Data Selection Criteria

To ensure that the data collected aligns with the objectives of this study, the following criteria were applied for both historical and current datasets:

a) Temporal Relevance

(1) For historical data, records from the year 1999 were selected to provide insights into the spatial and temporal context of that period.

(2) For current data, only the most recent datasets will be utilized, either through drone-based photogrammetry or existing data provided by the lecturer.

b) Data Completeness and Accuracy

(1) Historical maps and records must include clear cartographic details with minimal missing information.

(a) *For current data, photogrammetry or pre-existing datasets must provide high-resolution and georeferenced details to facilitate comparison with historical data.*

3) Data Collection Procedure

The data collection process followed a structured approach to ensure the accuracy and relevance of both historical and current datasets.

a) Historical Data Acquisition

(1) The historical data from 1999 was obtained from a lecturer at UiTM Shah Alam, who provided access to archival maps and records.

(2) These physical maps were scanned using high-resolution scanners, ensuring the preservation of cartographic details.

(3) The scanned maps were enhanced using image processing software to improve readability and prepared for digitization.

b) Current Data Collection

(1) Drone-Based Photogrammetry: A drone was deployed to capture aerial images of the study area. These images were processed using photogrammetry software to generate orthophotos and 3D models.

(2) Existing Data Acquisition: If available, high-quality and up-to-date spatial datasets provided by the lecturer were utilized. These datasets were validated for compatibility

4) Tools and Technologies

The data collection process utilized a combination of traditional and modern tools to ensure the accuracy and usability of both historical and current datasets.

a) Geographic Information System (GIS) Software

(1) GIS tools, such as QGIS, ArGis and Autocad, were used to digitize, process, and analyze both historical and current datasets. These tools enabled the integration of spatial data layers for comparative visualization.

b) Drone-Based Photogrammetry

(1) For current data, drone technology was employed to capture high- resolution aerial imagery of the study area.

c) Digitization Tools and Edit

(1) Historical maps provided by UiTM Shah Alam were digitized using high-resolution scanners to convert physical documents into digital formats. Image processing software, such as Adobe Photoshop, was utilized to enhance the clarity of scanned documents.

5) Lenticular Printing Technologies

Lenticular printing is a key component of this study, enabling the visualization of multiple perspectives on a single map.

a) Digital Printing Techniques

(1) High-resolution printers capable of producing precise interlaced images were used to create the lenticular layers.

b) Interlacing Software

(2) Software such as 3DmasterKit, Grape or specialized lenticular design tools was employed to prepare interlaced images by merging historical and current datasets into a single design.

c) Material Selection

(3) Printing was conducted on durable materials compatible with lenticular lenses, ensuring long-lasting and visually impactful outputs

6) Lenticular Lens Technologies

Lenticular lenses were utilized to achieve the desired interactive effect, where viewers can see different perspectives depending on their angle of view.

a) Lens Array Design

(1) The study employed lenses with optimal pitch and focal length, selected based on the map dimensions and the resolution of interlaced images.

b) Material Quality
(1) High-quality acrylic or PET lenticular sheets were chosen to ensure clarity and durability.

c) Alignment Tools
(1) Specialized alignment tools ensured the precise overlay of the interlaced images onto the lenticular lenses, achieving seamless transitions between perspectives.

C. Participant

The study will involve 30 participants selected from student which 10 of them is in studies in Science Geomatic who are interested in cartography, 10 students which does not lead to cartography and 10 from the common student which do not study in Science Geomatic. Participants will be chosen using this method, ensuring a diverse group that represents different levels of familiarity with historical content and interactive maps.

$$\boldsymbol{n = \frac{N \times Z^2 \times p \times (1-P)}{e^2 \times (N-1) + Z^2 \times p \times (1-p)}}$$

N = 50
Z = 1.96 (for 95% confidence level)
P = 0.5 (assuming maximum variability)
e = 0.05 (5% margin of error)

a) Calculate Z^2

$$Z^2 = 1.96^2 = 3.8416$$

b) Calculate $p \times (1-p)$

$$0.5 \times (1 - 0.5) = 0.25$$

c) Numerator

$$\mathrm{N} \cdot Z^2 \cdot \mathrm{p} \cdot (1 - \mathrm{p}) = 50 \times 3.8416 \times 0.25 = 48.02$$

d) Denominator

$$e^2 \times (\mathrm{N} - 1) + Z^2 \times p \times (1-p) = 0.05^2 \times (50-1) + 3.8416 \times 0.25$$
$$e^2 = 0.0025$$
$$0.025 \times 49 + 0.9604 = 0.1225 + 0.9604 = 1.0829$$

e) Final Sample Size

n = 48.02/1.0892
= 44.34
= 44 participants

For a population of 50, the required sample size is approximately **44 participants** to achieve a 95% confidence level with a ±5% margin of error.

CONCLUSION

Lenticular cartography offers a novel approach to enhancing historical perspective through interactive map visualization. By integrating dynamic visual elements, this method provides an engaging way to explore historical changes, fostering a deeper understanding of spatial and temporal relationships. Its potential applications extend to education, tourism, and cultural heritage, making it a valuable tool for preserving and communicating historical narratives.

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FLOOD RISK AND MITIGATION STRATEGIES OF HISTORIC BUILDING IN PRIMARY HERITAGE ZONE KUALA LUMPUR: A REVIEW

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ABSTRACT

Rapid progression of climate change has significantly impacted weather patterns worldwide, leading to an increased frequency of natural disasters. Flooding, particularly from localized rainfall due to convective storms, has become a critical concern in Kuala Lumpur. As a result, historic buildings are at high risk of deterioration from recurrent flooding. The age of these buildings makes them inherently vulnerable, as they were constructed using techniques and materials with limited resistance to floodwater. This study aims to assess flood risks to heritage buildings and explore both local and international best practices for flood mitigation strategies to preserve Kuala Lumpur's heritage sites. The methodology includes an in-depth review of relevant journals, reports, existing regulations and guidelines published by government and private agencies. The study found that the risks posed by flooding to historic structures can be classified into two types: structural and material damage (potential structural integrity issues and long-term degradation) and the loss of historical and aesthetic value (loss of original materials, discoloration, and algal growth). Furthermore, lack of flood-specific conservation guidelines for heritage buildings in Malaysia was identified as a key issue. The study identified reliable existing practices, such as "Garis Panduan Pemuliharaan Bangunan Warisan" and the National Heritage Act 2005 (Act 645) in Malaysia, as well as international guidelines like those on Flood Adaptation for Rehabilitating Historic Buildings, United States, and the Netherlands' sustainable urban drainage systems (SUDS), that can be adapted to protect historic buildings in the Malaysian context. The anticipated outcomes of this study include the development of recommendations derived from the analysis of existing guidelines to address flood risks for historic buildings. These findings will be validated through interviews with professionals responsible for flood management and heritage conservation. Significance of these results is to bridge the gap between international best practices and Malaysia's unique climatic and cultural context, enhancing the resilience of Kuala Lumpur's heritage buildings.

Keywords: Flood Risk, Historic Buildings, Mitigation Strategies, Primary Heritage Zone Kuala Lumpur.

I. INTRODUCTION

The rapid shift in climate change has significantly affected local weather patterns worldwide. However, its impact varies depending on regional climate conditions and geographical scale (Mehta & Yadav, 2021). One of the most concerning consequences of climate change is the increasing occurrence of natural disasters. As illustrated in Figure 1, data from the Global Reported Natural Disasters by Type indicate a rising trend in disasters from 1970 to 2024, with floods showing the most significant increase. In Malaysia, flash floods and landslides have become more frequent due to rising rainfall intensity (Jahara et al., 2021).

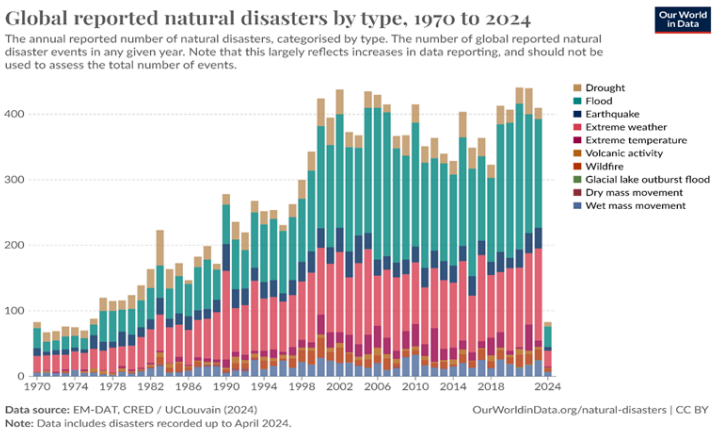


Figure 1.0 Global Reported Natural Disasters by Type, 1970 to 2024 (Our World in Data,2024)

According to data from the Department of Irrigation and Drainage Malaysia, 36 flood events were reported in Kuala Lumpur between 2018 and 2022. This frequently occur in KL due to brief, localized rainfall caused by convective storms, which result from the rapid ascent of humid air as the sun heats the Earth's surface (Miniandi et al., 2024). Moreover, the risk of flash floods rises between September and October as average monthly rainfall increases during the monsoon transition (METMalaysia). Consequently, the Kuala Lumpur area, including its buildings and facilities, are subjected to be affected and thus cause costs by dislocation, disruption and physical damages (Bhuyan et al., 2018). During the 2021 flood disaster, Kuala Lumpur recorded RM32.4 million in losses for damage to living quarters, according to the Department of Statistics Malaysia. Although this was not the highest loss recorded compared to other states, the repair costs remain significant.



Since 1981, extreme rainfall has intensified in Kuala Lumpur's urban areas compared to its surrounding rural regions (Yafei et al., 2020). As Kuala Lumpur continues its transformation into a modern capital, rapid urbanization has exacerbated the occurrence of flash floods. This phenomenon is closely linked to urban expansion, which has led to the reduction of green spaces and forests, replacing natural surfaces with rooftops and concrete structures that limit water absorption (Hassan et al., 2022). This increasing flood risk poses a significant threat to heritage buildings in Kuala Lumpur, as these structures are inherently vulnerable due to their construction techniques and the use of materials with limited resistance to floodwater (Snelling et al., 2023).

Given Kuala Lumpur's status as a renowned tourist destination, preserving its heritage buildings is essential, as they serve as key attractions. The city's proximity to major rivers, such as the Klang River, has shown a consistent increase in stream flow and can rapidly cause flash floods during periods of heavy rainfall (Nor et al., 2018). Kuala Lumpur contains several heritage zones, but this discussion focuses on the Primary Heritage Zone, where many historical buildings are located near rivers and are frequently exposed to flood risks. Under

the Draft Kuala Lumpur Local Plan 2040, this zone includes historical buildings gazetted under the National Heritage Act 2005.

While no substantial flood-related damage has yet occurred to these structures in Kuala Lumpur, repeated exposure to recurring floods will inevitably lead to deterioration, compromising both their structural integrity and aesthetic value. Furthermore, Malaysia currently lacks effective flood mitigation practices specifically tailored to heritage sites, heightening the risk if a major flood were to impact the city. Although conservation guidelines, such as the Guidelines for Heritage Building Conservation (2017), are in place, they do not focus explicitly on protecting heritage buildings from flood damage. By contrast, other nations have developed specific guidelines for flood adaptation in historic buildings. For example, the U.S. Department of the Interior's National Park Service (NPS) published the Guidelines on Flood Adaptation for Rehabilitating Historic Buildings to provide detailed recommendations for improving flood resilience in historic structures.

Given the growing frequency and severity of floods, failure to adopt and establish proactive measures endangers these historic structures and the cultural heritage they represent. Therefore, this justifies the need for integrating international best practices and establish the new guidelines in the local context, ensuring that Malaysia's heritage buildings are protected while retaining their local authenticity and resilience against future flood risks.

II. METHODOLOGY

This research began by reviewing relevant literature on the potential flood risks to historical buildings in Malaysia. The sources included technical reports and records from government and private agencies, books, periodicals, and academic publications. Articles were retrieved from platforms such as Google Scholar, SciSpace, and online databases like ScienceDirect and Scopus. Additionally, the reference lists of these articles were reviewed to identify further studies, as there is limited research specifically focusing on the impact of flood risks on historical buildings. The gathered information was divided into two sections: the impact of flood risks on structural and material damage, and the loss of cultural significance and values.

The methodology employed in this study also involved a comprehensive review of existing local and international guidelines and strategies for mitigating flood risks. Since no prior studies have specifically examined how existing strategies in Malaysia can be adapted to protect historical buildings from flood risks, each section of the national conservation guidelines, Garis Panduan Pemuliharaan Bangunan Warisan 2016, was thoroughly reviewed and compared with the National Heritage Act 2005 to identify principles and conservation guidelines that could be adapted. Various strategies were also reviewed, including the Stormwater Management and Road Tunnel (SMART) Project, designed to mitigate flooding in Kuala Lumpur. Recent research on flood hazard mapping, which focuses on assessing flood risks in urban heritage districts, was also considered.

International strategies and guidelines were examined to identify suitable approaches that could be adapted to the local context of Kuala Lumpur. Notably, the Guidelines on Flood Adaptation for Rehabilitating Historic Buildings (2021) from the National Park Service (NPS) in the United States were carefully studied to identify strategies that could be implemented for historical buildings in Kuala Lumpur. Additionally, the Netherlands' Sustainable Urban Drainage System was reviewed to understand how an effective drainage system could be managed in Kuala Lumpur to prevent flooding.

III. FLOOD RISKS TO HISTORICAL BUILDINGS

A. Structural And Material Damage

Floodwaters exert hydrostatic and hydrodynamic pressures on heritage buildings, resulting in structural issues like cracks, wall collapses, and foundation instability. As floods can create fissures, compromise structural integrity, and even lead to the collapse of historic buildings (Trizio et al., 2022). The potential risk is also the flood-induced pressures, coupled with soil saturation and erosion, caused substantial structural damage to churches and vernacular architecture (Petronijevic, 2022). The prolonged exposure to moisture also can result in discoloration or algal growth, permanently altering the appearance of these structures (Lucia et al., 2024).

Additionally, porous materials such as stone and mortar, commonly used in heritage structures, can be in serious source of damage for the masonries from the presence of the moisture (Oliveira et al., 2023). Several studies have been demonstrated that rising damp can accelerate and be responsible for the degradation of historical building structures (Congedo et al., 2021). Furthermore, the waterlogged building materials experience long-term degradation processes, including moisture retention, algal growth, and biodegradation. For example, adobe walls can disintegrate after repeated soaking and drying cycles, and plaster often detaches from walls following prolonged exposure to water (Petronijevic, 2022).

B. Loss Of Cultural Significance Value

Flooding can lead to the irreversible loss of cultural significance associated with historical buildings, which hold immense value for specific places and communities. Cultural significance, as defined by The Burra Charter (2013), refers to the aesthetic, historic, scientific, social, or spiritual value for past, present, or future generations. In certain locations, historical buildings reflect societal values and dignity through their structure and functions. These buildings are crucial in expressing cultural identity, as they encapsulate the values and traditions of the community (Lanciotti, 2024). They serve as symbols of continuity, connecting past generations with the present and future, thereby reinforcing cultural narratives (Erdemir & Basar, 2019).

As flooding events become more frequent, there is increasing concern that these buildings will lose their cultural value, affecting their fabric, function, and the communities that rely on them. The Busayin Shrine, located at the Osun-Osogba Sacred Grove in Nigeria, suffered severe damage from seasonal flooding in 2019. The mud-based concrete supporting the shrine's pillars was damaged, and the roof collapsed. This loss has had a devastating impact on the local community and traditional priests, who can no longer use the shrine safely (Banja, F., 2024). Not only did the flood risk affect the structure, but it also disrupted the shrine's use, as well as the daily and spiritual practices of the community.

Furthermore, flooding events have the potential to destroy original materials and artifacts of significant historical importance, diminishing the evidential value of heritage sites. Building materials that hold cultural and historical significance can also be damaged. For example, the corrosive, salty floodwaters damaged the ancient marble floors of St. Mark’s Basilica during the Venice floods of 2019, causing parts to chip and go missing, as reported by NBC News on 2019. This led to substantial damage to the church's overall artistic and architectural value. The aesthetic appeal of heritage buildings is often reduced due to physical damage or incomplete restoration efforts. While some heritage assets may recover their original value after restoration, others may suffer a partial or complete loss of value despite repairs (Valles et al., 2020). In some cases, the physical damage and remnants of structures that retain historical significance may generate new symbolic value (Salazar et al., 2024), but the aesthetic value of the historical structure could be significantly lost.

IV. EXISTING GUIDELINES AND STRATEGIES

A. Local Guidelines and Strategies

Recent research by Dina D ’Ayala (2020) has focused on developing flood hazard mapping techniques to assess flood risks in urban heritage districts. This research utilizes flood hazard maps to illustrate flood extent and water depth for different types of flooding, including pluvial (surface water) and fluvial (river) floods. The maps are generated using time-series data collected from rainfall and river gauges, allowing researchers to calculate rainfall intensity and river hydrographs over various return periods. This approach enhances the understanding of how different flood scenarios affect the vulnerability of traditional buildings. As a result, flood hazard mapping can serve as a valuable tool and non-structural measures in developing targeted flood mitigation strategies, particularly for the preservation of historical structures in flood-prone areas.

In the same research, highlighted that SMART Tunnel in Kuala Lumpur plays a pivotal role in urban flood mitigation while simultaneously supporting transportation flow in a high-density city. This dual-purpose infrastructure becomes particularly relevant when evaluated in the context of historic urban zones that are vulnerable to recurrent flooding. This tunnel is unique as it is the only one in the world that integrates both wet and dry systems (Isah., 2015). However, The SMART Tunnel has a measurable but limited effect on reducing flood risk within the studied heritage district of Kuala Lumpur. While it is effective in diverting excess water from the Klang River during intense rainfall events, its impact on the specific study area, primarily influenced by the Sungai Bunus, is relatively minor. The tunnel reduces peak water depths during fluvial floods, lowering them from approximately 1.4 meters to about 1 meter. However, the spatial extent of flooding and the number of heritage buildings affected remain largely unchanged, with around 20% to 24% of the buildings still experiencing inundation. This suggests that although the SMART Tunnel contributes to overall urban flood mitigation, it does not provide sufficient localized protection for smaller tributary-influenced zones, highlighting the need for more targeted flood control strategies within vulnerable heritage areas.

The existing guidelines and regulations in Malaysia, such as the Garis Panduan Pemuliharaan Bangunan Warisan (2016) and the National Heritage Act 2005, lack specific strategies for conserving historical buildings from flood risks. This gap between the guidelines and current challenges highlights the need to develop new strategies while ensuring compatibility with existing conservation principles. The difficulty lies in integrating flood management measures either directly into heritage buildings or within the broader heritage zone while adhering to established preservation guidelines. Therefore, review current regulations to incorporate effective flood mitigation strategies requires careful consideration to balance both heritage conservation and disaster resilience. Furthermore, the importance of aligning flood mitigation strategies with national planning legislation, such as the Town and Country Planning Act 1976 (Act 133), cannot be overstated, especially when addressing risks in heritage-sensitive zones. This act serves as the legal foundation for land use planning,

zoning control, and environmental protection in Malaysia, offering a framework within which infrastructure projects must operate. However, many traditional urban areas, including historic districts, were developed before comprehensive flood-related planning mechanisms were institutionalized. Urban resilience strategies must therefore integrate both Acts, Act 133 for planning and zoning, and the Heritage Act for cultural protection, within a unified benchmarking framework. This dual compliance ensures that flood mitigation efforts not only reduce physical risk but also align with legal responsibilities to conserve national heritage.

B. International Guidelines and Strategies

Flood management is a complex and challenging task, and it is a global issue that requires careful planning, resource allocation, and effective public communication. In the United States, the National Park Service (NPS) has developed a comprehensive set of guidelines titled "Guidelines on Flood Adaptation for Rehabilitating Historic Buildings" (2021), which provides a structured approach to enhancing the flood resilience of historic properties while preserving their architectural and cultural significance. These guidelines outline key strategies for flood adaptation, including site and landscape modifications, as well as planning and assessment measures for flood risk reduction. These strategies are applied to buildings at risk of flooding and aim to minimize the impact of floods, focusing on both the building and its surrounding site and landscape. The goal is to conserve the building's features and materials, preventing severe damage. The guidelines also include temporary protective measures, such as protecting utilities and filling basements. These treatments are typically temporary and are only applicable under specific conditions for certain types of buildings. The focus is on how to safeguard basements and utilities within historical buildings.

Furthermore, the guidelines present two floodproofing strategies: Dry Floodproofing and Wet Floodproofing. Dry floodproofing is only suitable for load-bearing masonry or frame buildings and is not recommended if flooding is expected to exceed three feet. On the other hand, wet floodproofing is not appropriate if flooding is anticipated to last longer than 24 hours, as prolonged exposure to floodwaters can cause significant damage to historic materials, features, and finishes. Additionally, the guidelines propose treatments that involve adjustments or additions to the historical buildings, such as elevating the building on a new foundation or raising its interior structure. This may be a viable alternative to elevating the entire structure. All work must adhere to conservation principles, aiming to protect the building's structure while retaining its historic materials, features, and finishes, especially those that are resistant to flood damage. Lastly, the guidelines suggest two more treatment options: abandoning the lowest floor by relocating all living spaces to higher floors (though this requires additional technical considerations depending on floodproofing measures) and relocating the entire building to a new site by detaching it from its foundation. However, relocating historical buildings is generally not recommended as a preservation practice, as it can negatively impact the community and the originality of the structures.

Beyond the United States, the Netherlands has implemented a comprehensive water management strategy to mitigate flood risks in urban areas, particularly in Rotterdam. This approach integrates sustainable urban drainage systems (SUDS), which include green roofs, permeable pavements, and water plazas that temporarily store excess rainwater, thus reducing the risk of flooding in surrounding heritage zones. By combining flood risk management with urban greening initiatives, Rotterdam illustrates how sustainable infrastructure can enhance climate resilience while protecting historical buildings (Holicky & Sykora, 2010). This strategy highlights how large-scale projects can be interconnected and how such guidelines can serve as effective strategies for flood adaptation, helping to safeguard historical buildings from flood risks.

CONCLUSION

Flood management for heritage buildings is a global challenge that requires a careful balance of preservation and resilience. Around the world, the declining effectiveness of traditional flood mitigation measures poses a significant threat to historical buildings. The existing strategies and guidelines, both locally and internationally, offer various approaches to safeguarding these structures. In Malaysia, while initiatives like the SMART Tunnel and flood hazard mapping show progress in addressing flood risks, there is still a gap in incorporating these measures into heritage conservation guidelines. Similarly, international guidelines, such as those from the United States and the Netherlands, provide valuable insights into flood adaptation techniques like floodproofing and water management systems. However, the challenge remains in adapting these strategies to local contexts, ensuring that they are effective while preserving the cultural, historical, and aesthetic value of the buildings. The lack of specific flood mitigation strategies in Malaysia's existing conservation guidelines underscores the need for a review and adaptation of these measures to better address current challenges. Just as inconsistent regulations can cause confusion and hinder effective implementation, the integration of flood management strategies into heritage conservation must be streamlined and improved. The findings from both local and international cases highlight the need for a comprehensive, context-specific approach to safeguarding heritage buildings from flood risks. Thus, there is an urgent need for continuous evaluation of current guidelines

and regulations, incorporating new technological advancements and methodologies, to ensure the successful protection of cultural heritage in flood-prone areas.

ACKNOWLEDGMENT

Alhamdulillah, all praise to Allah for His blessing and strength given to me throughoutthe completion of review paper and research journey. Alhamdulillah, I thank Allah for giving me health and patience to overcome every problem occurs with ease during the writing of the research. First and foremost, I would like to express my deepest appreciation and gratitude to my supervisor, Dr Nur Farhana Binti Azmi, for her effort and patience throughout the process of this study and research. I truly appreciate her continuous support, guidance, comments and suggestions which allowed the research to be completed. Her guidance and advised helped me in all the time of this writing and whenever I am confused during the process of writing this research.
Next, special thanks to our thesis conductor Associate Prof. Sr. Dr. Zuraini Binti Md Ali for opportunity to being involve in the ISCU 2025. Thank you for the valuable inputs and encouragement towards the improvisation of the research as a whole. Sincere thanks to my course mate and to all those who have help me along the research journey. Finally, an honourable mention goes to my family member. I am forever indebted and thankful towards both my parents Zainal Bin Mohd Sam and Nayati Binti Maskun for their endless duas, faith and unconditional love. Also, to my beloved sisters, brother-in-law, and nephew for always believing in me and stood by me. Without their support and encouragement, I may be faced difficulties in finishing this research.

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ACHIEVING ZERO ACCIDENTS IN THE CONSTRUCTION INDUSTRY – A STUDY OF EFFICIENCY OF SAFETY MANAGEMENT AND APPLICATION IN HIGH-RISE BUILDING CONSTRUCTION PROJECTS IN KLANG VALLEY

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ABSTRACT

The construction industry is inherently hazardous, and high-rise building projects present a number of risks to workers, including falls, equipment-related accidents, and structural failures. While safety management practices have evolved over the years, zero accidents remain an elusive goal. The nationwide occupational accident rate in Malaysia dropped by 20% in 2020 compared to 2019, while workplace death cases decreased significantly by 45%. According to Deputy Human Resources Minister Datuk Awang Hashim, 32,674 occupational accidents were recorded in 2020, with 312 being fatal. This reduction brought the occupational accident rate to 2.18 per 1,000 workers, down from 2.71 in 2019. Similarly, the workplace death rate declined to 2.09 per 100,000 workers in 2020, compared to 3.83 in the previous year. Even though safety protocols do exist, little is understood about their actual implementation and effectiveness in attaining zero accidents within high-density urban regions like the Klang Valley. The study will thus try to evaluate the present status of safety management frameworks being practiced, identify potential barriers impeding the realization of zero accidents, and develop actionable recommendations to enhance safety performance. A mixed-method approach was used that combined quantitative surveys targeting key stakeholders such as project managers, safety officers, and construction workers, with qualitative in-depth interviews into safety practices. Data on high-rise construction sites were analyzed to analyze the correlation of safety management efficiency with accident rates. Some of the key findings from the review show that even though the response for safety management systems implementation was highly positive, significant lapses persist in terms of worker training, hazard communication, and monitoring to ensure compliance. It was further noted in this study that highly committal leadership coupled with very active worker participation reduces accident rates on projects. The findings will contribute to targeted improvements in safety training, real-time hazard monitoring, and inculcating a safety-first culture in realizing the goal of zero accidents.

Keywords: Construction, High-rise, Safety and health, Safety management, Zero accidents

I. INTRODUCTION

Since independence, Malaysia's construction industry has grown, and most capital formation is derived from construction activities. These days, one of the most significant and fruitful sectors of the Malaysian economy is the building industry. Since the 1970s, Malaysia, a rapidly developing country in Asia, has recognized the importance of the building industry in raising citizens' standards of living and contributing to economic progress.

The construction sector is another significant industry that is essential to a nation's socioeconomic development. Economically speaking, it makes a major difference in a nation's total GDP. Among other industries, including manufacturing, services, agriculture, import duties, and mining and quarrying, the industry has made the biggest contribution. In the third quarter of 2024, the value of work completed in the construction industry totalled RM41.91 billion (Q2 2024: RM38.9 billion), representing a significant increase of 22.9 percent, which was better than the 20.2% achieved in the previous quarter (Department of Statistics Malaysia, 2024).

The challenge for construction researchers and practitioners is to create work systems that are both highly productive and highly reliable, and that can operate safely and effectively in the dynamic, complex, and competitive conditions of construction projects, given the constant pressures for speed, productivity, and competitiveness (Mitropoulos et al., 2009). This calls for innovative methods of safety management as well as a deeper comprehension of the aspects and procedures of the workplace that lead to accidents. In order to establish a high-performance safety culture, construction companies must view safety and health as a strategic tool that, when used properly, can increase profit and competitiveness rather than as merely another way to prevent unintended accidents or federal fines.

According to Hirschmann (2021), the accident rate starting in 2020 was lower than the previous year due to several construction projects being put on hold due to the COVID-19 pandemic (Hirschmann, 2021).

1.1 Problem Statement

The construction industry in Malaysia, particularly in high-rise building projects, is widely recognized for its hazardous working environment. Despite the implementation of safety regulations and policies, accident rates in the construction sector remain a significant concern, contributing to injuries, fatalities, and financial losses. In 2020, Malaysia recorded an occupational accident rate of 2.18 per 1,000 workers, with the construction industry accounting for a large proportion of these incidents (DOSH Malaysia, 2020). Klang Valley, being a hub for high-rise construction, experiences heightened risk due to the complexity and scale of its projects.
Contractors' safety management practices, such as their failure to provide personal protective equipment, hold frequent safety meetings and provide safety training, are seriously concerning. Accordingly, the biggest effects of construction site accidents on businesses include high expenses, timetable disruptions, damage to the company's reputation and hardship for employees and others (Tam et al., 2004).

When it comes to adopting safety management as a comprehensive procedure for reaching zero incidents and creating a high-performance safety culture, the construction sector has generally trailed behind other industries. The primary cause of this has been the belief that implementing safety as a comprehensive management process in the construction sector is challenging. "Total safety measurement," which entails determining and quantifying the elements that significantly impact safe behaviours, is one facet of this comprehensive approach to safety that has most irritated the construction sector. The primary issue identified is the challenge of determining what should be measured and how to quantify it, especially when it comes to the intangible components of safety. The idea of continual improvement is difficult to implement without measurement.

1.2 Aim

The strategic goal of this research was to achieve zero accidents by creating a high-performance safety culture on construction sites through the development of a strategic framework for ongoing safety improvement. In order to establish the genuine and overall safety performance of a construction organization, this framework included the important elements in each of the four dimensions-person, culture, behavior, and process.

1.3 Objectives

The following objectives are formulated to achieve the aim of this study. In order to achieve the aim and answers the research objectives, here are the research objectives:

1. To evaluate the level of safety in the construction sector at the moment and determine whether construction firms should handle safety as a whole process.
2. To determine the elements that affect a construction organization's overall safety environment and that are suitable for enhancement, thereby serving as a key component of strategic safety improvement.
3. To propose a strategy framework for defining, assessing, and enhancing overall safety in the construction sector in order to reach the zero-accident target.

II. LITERATURE REVIEW

2.1 Current State of Safety in Construction

Safety in construction projects is a critical concern due to the industry's inherent hazards, including falls, electrical risks, and exposure to hazardous materials. Implementing comprehensive safety measures, such as fall protection systems, electrical safety training, and proper handling of hazardous substances, is essential to mitigate these risks. In Malaysia, the Department of Occupational Safety and Health (DOSH) emphasizes the importance of safety management systems and the adoption of a safety culture at all levels of construction,

from top management to on-site workers (Official Website Department of Occupational Safety and Health - Practise Safety at Construction Sites, 2021). Recent incidents, such as the tragic death of a 12-year-old boy due to inadequate site security in Perth, Australia, highlight the consequences of neglecting safety protocols (Kirk, 2024). Therefore, adherence to safety regulations and the promotion of a safety-conscious environment are imperative to prevent accidents and ensure the well-being of all individuals involved in construction projects.

Studies indicate that the creation and execution of successful safety initiatives lowers the number of accidents. Regretfully, many people do not believe that safety is essential to the success of their initiatives when it comes to investing time and resources in it. This mindset results from a failure to understand that, in addition to lowering workplace injuries, successfully implementing project safety measures can also lower workers' compensation premiums by 50 to 90 percent and the indirect costs of accidents by an equivalent amount (CII, 1993).

The industry has made significant progress in the past few decades in determining and removing the reasons behind construction site accidents. Safety has emerged as one of the key areas of focus on many building sites. In addition to lowering workplace injuries, construction companies are learning that their initial investment and ongoing efforts to maintain a strong safety record pay off by helping to complete projects "on time" and "within budget."

It is challenging to identify risks in the construction sector since worker locations change frequently, and work progresses as the project moves forward. Accordingly, the risk that employees encounter varies according on their location and activities (McDonald et al., 2009). Inadequate safety concerns on building sites have a physical and psychological impact on employees and their families, which raises direct and indirect expenses for the project (Bansal 2011).

2.2 Effectiveness of Dosh as a Strategic Safety Improvement Organization

In Malaysia, the Ministry of Human Resources oversees the Department of Occupational Safety and Health (DOSH). With the exception of jobs listed in the First Schedule of the Occupational Safety and Health Act 1994 (Act 514), this department is in charge of protecting others from health and safety risks that arise in all workplaces across Malaysia, including those run by the public sector and statutory authorities. With their mission to ensure safety and health at work, credible statistics reveal that DOSH has had a beneficial influence on the Malaysia construction industry in terms of reducing workplace accidents and occupational injuries. Undoubtedly, DOSH has played a pivotal role in the development of a safer work environment over the years.

According to DOSH, competent person in OSH is a person appointed by the employer and authority to have appropriate training, knowledge, experience and skill to carry out specific task. The National Occupational Accidents and Diseases Statistics show that the number of accidents decreased between 2015 and 2019. In the meantime, a recognized competent person indicates a 3.07 growth in 2019. According to this research, a higher number of competent individuals helps lower the workplace accident rate. By showing their level of competence and helping to lower the accident rate, competent individuals can manage occupational safety and health (OSH) in industries with the support of National Institute of Occupational Safety and Health (NIOSH), the registered training provider.

However, for a variety of reasons, the agency continues to face harsh criticism from construction associations. Despite a notable decline in workplace accidents and fatalities in the construction industry since the implementation of OSHA regulations, construction firms have maintained a negative view of OSHA's rules and guidelines. This persists despite the agency's continuous attempts to promote outreach, training, and consulting services.

To determine if the construction industry needs a strategic safety enhancement framework focused on achieving incident and injury-free work settings, it is essential to analyse why OSHA has not fully succeeded in achieving and sustaining the aim of zero accidents in the field.

2.3 Effectiveness of Personal Protective Equipment (PPE) In Achieving Zero Accidents

"PPE" stands for personal protective equipment, which is gear worn to reduce exposure to risks that result in severe diseases and injuries at work. Contact with chemical, radioactive, physical, electrical, mechanical, or other occupational dangers may cause these illnesses and injuries. Gloves, safety glasses, shoes, earplugs or muffs, hard hats, respirators, coveralls, vests, and complete body suits are examples of personal protection equipment (Personal Protective Equipment - Overview | OSHA.gov | Occupational Safety and Health Administration, 2025).

The success of PPE in attaining zero accidents in the construction industry has proven to be by mitigating injuries' severity while minimizing risk exposures associated with hazardous activities. PPE is the last line of defense between the worker and injury should all the engineering controls or administrative controls fail.

It must, therefore, be appropriately selected according to the task-specific risks, be maintained adequately, and used consistently by trained personnel in an organization to be effective. It involves mandatory PPE use in workplaces that result in fewer injuries or fatalities than those not involving such adoption. Crucially, PPE does not completely prevent accidents; it is part of a comprehensive safety management system that includes hazard removal, risk evaluation, employee training, and consistent supervision.

2.4 Health, Safety and Environmental Standards

Based on Sunway Sustainability Report 2023, Sunway Group is driven by the Occupational Health, Safety, and Environment Policy, which echoes a strong sentiment for the well-being and safety of employees and all stakeholders across business operations. This is intended to define not only a safe and healthy workplace, but also compliance with relevant laws and rules applied to industry best practices and to continuously improve. Through its total OHSE Management System (OHSEMS), Sunway protects 100% at work, also meeting critical regulations such as those of Occupational Safety and Health Act 1994 (OSHA 1994), Factories and Machinery Act 1967 (FMA 1967), and Environmental Quality Act 1974 (EQA 1974). It has set up regular internal and external audits like the 2023 Group OHSE Corporate Audit to check compliance with both local and international standards. The Lead Auditors certified for ISO 45001:2018 OHSMS carried out these audits to check all Sunway sites for OSHA 1994 compliance, thus demonstrating a holistic approach to occupational health and safety management by the Group.

Audits are performed by engaging local third-party entities to facilitate these external audits for regulatory bodies like the Malaysian Society for Occupational Safety and Health (MSOSH) for award audits, as well as international certification bodies such as the Malaysian Society for Quality in Health (MSQH) and Australian Council on Healthcare Standards (ACHS). Commitment to Occupational Health, Safety, and Environment (OHSE) is further elaborated through an internal dashboard that is updated on an annual basis, indicating Sunway's progress and performances across the various divisions of its businesses.

III. RESEARCH METHODOLOGY

The methodological approach to this investigation will be described and explored in this chapter. First, the goal and methodology of the study will be presented. The next topic to be covered is the research plan, which includes data collection (literature review, documentation, and interview), sample selection (case study), and data analysis (Statistical Package for the Social Sciences, or SPSS).

3.1 Research Design

The purpose of research for this study was selected as a descriptive method that involved gathering data to address the questions related to the research subject. This is due to the fact that, as noted by Fraenkel and Wallen (1996), the descriptive method serves to clarify, analyze, and categorize an item using different techniques such as surveys, interviews, questionnaires, observations, and written texts. This kind of research aims to uncover the answers to questions about who, what, where, and how. It was intended to depict the traits of a population (Saunders et. al., 2009).

This research consists of four methodological phases: literature review, case studies, structured interview, and evaluation. The aim of this research is to determine the factors that contribute to the decreasing number of accidents in the construction industry. The researcher is focusing on the construction sector in Malaysia, aiming to gain a deeper understanding of the industry by analyzing the present performance of the Malaysian construction domain through research. These will assist the researcher in pinpointing the problematic areas and seeking to implement corrective measures for the safety issue. Consequently, this research can be characterized as descriptive.

3.2 Research Methodologies

In this research, there are many sources of evidence and is separated into two categories which are primary and secondary source. Primary source may include questionnaire survey and interviews and as for secondary source, literature review and documentation. To identify the elements that lead to the reduction of accidents in the construction sector for the successful execution of construction projects; numerous studies, articles, and journals are being examined to gain a deeper insight into the research.

Literature Review

A literature review is an assessment of data gathered from relevant literature in the chosen subject of study. A literature review is completed by reading more from scholarly publications, instructional books, and online resources. This phase aims to give researchers a great place to start when they start a new study in a different

field and, more crucially, to make sure that researchers don't repeat previously completed work. In addition, to identify the gaps in previous study.

Sample Selection

A solitary case study regarding the elements that lead to the reduction of accidents in the construction sector was selected for sample analysis. The study could be deemed invalid or insignificant if the incorrect individuals are interviewed. Initially, the sample companies were informed through email about the purpose of this study. To achieve the research objective, it was essential to connect with individuals who had the greatest expertise and understanding of the research domain, specifically engineers, site supervisors, safety and health personnel, contractors, and others.

This study compares the adoption of safety procedures in building projects by analysing the causes and effects of construction activities on safety using the case study concept. Two different construction sites are chosen from two different company to study their best practices. The following criteria, which are listed below, are used to select the case study:

- The project must be a high-rise building construction project in Klang Valley
- The project must be completed or post construction for practicality and ease of research
- The current practice of safety management

Evaluation

During this stage, the collected data was processed and examined for findings. The conclusions drawn from the analysis are then assessed, addressed about, and summed up. The findings are then interpreted, assessed, and discussed in order to draw a conclusion. On the basis of the findings, a few suggestions are made to enhance the research. As a result, the outcomes are far more valid and dependable.

IV. EXPECTED FINDINGS

The subsequent logical step following the collection of information was to examine the available data gathered from the respondents via the structured interview. The data gathered will be analysed using the Statistical Package for Social Science (SPSS) software. SPSS is an extensive system for data analysis; it can produce tabulated reports, charts, descriptive statistics, distribution plots, and intricate statistical analyses from any kind of data file.

From the research methodology, the anticipated results will be divided into three types of categories to be analysed. The first category is where the respondent was asked about the research questions and a little bit about their background like name, education background, role of respondent in the construction site and working experiences. The second category is where the respondent was asked regarding factors that contribute to the decreasing number of accidents in the construction industry and other general questions related to safety and health. The third and the last category is where the respondent was asked about their company's best practices in safety and health and a proposed strategy framework for defining, assessing, and enhancing overall safety in the construction sector to reach the zero-accident target.

CONCLUSION

It is anticipated that the framework will give a construction company a way to measure and enhance its strategic safety performance. With the help of this framework for strategic improvement, a contracting organization could concentrate its efforts on the elements that would strategically enhance the organization's safety performance and offer chances for ongoing safety improvement, ultimately leading to the achievement of zero accidents.

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THE EFFECTS OF SHORT-TERM RENTALS ON URBAN HOUSING MARKETS IN MALAYSIA

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ABSTRACT

The emergence and rapid growth of short-term rental (STR) platforms have significantly transformed urban housing markets in Malaysia. While STR offers economic benefits for property owners and contributes positively towards the tourism sector, it presents challenges related to housing affordability and the availability of long-term rental properties. This study aims to examine the impact of STRs on Malaysia's urban housing markets. In recent years, STR platforms have facilitated a new way for property owners to generate income by renting out their properties to short-term visitors. This has proven to be a lucrative opportunity, especially in major urban centres and tourist hotspots. However, STRs have been associated with rising rental prices and the potential reduction in the availability of long-term housing options, as more property owners opt for short-term rentals over traditional long-term leases. The study will provide valuable insights into the broader implications of the STR phenomenon. Policymakers, urban planners, and industry stakeholders will be equipped with a more nuanced understanding of the economic and social impacts of STRs. Ultimately, the goal is to inform the development of balanced strategies that maximise the benefits of STRs such as economic growth and enhanced tourism, while addressing their potential negative effects on housing stability and affordability. This study seeks to contribute to the formulation of policies that support sustainable urban development and equitable housing solutions in Malaysia.

Keywords: Short-Term Rentals (STRs), Urban Housing Markets, Housing Affordability, Rental Prices.

I. INTRODUCTION

The rapid rise of short-term rental (STR) platforms such as Airbnb, Booking.com, and Agoda has significantly transformed Malaysia's housing, rental, and tourism landscapes. These platforms enable property owners to rent residential units to tourists and business travelers for brief periods, offering a flexible, often more affordable alternative to traditional hotels. The growing popularity of STRs reflects a global trend toward platform-based, peer-to-peer accommodation services, which provide travelers with unique, localised experiences. However, this growth has also raised critical concerns regarding its broader impacts on urban housing markets and residential communities.

In Malaysia, the proliferation of STRs has contributed to disruptions in long-term rental supply, rising property prices, and changes in neighborhood dynamics. As more residential units are converted into short-term accommodations, the availability of affordable long-term housing for local residents' declines. This phenomenon is particularly evident in metropolitan areas and tourism hotspots, where residents face increasing difficulty securing stable housing. Moreover, the influx of transient visitors into residential neighbourhoods often leads to overcrowding, noise complaints, and the erosion of community cohesion-especially in strata properties where shared facilities are impacted.

The situation is further complicated by Malaysia's fragmented and underdeveloped regulatory environment. The lack of a unified legal framework for STRs has resulted in inconsistent enforcement, legal uncertainty for property owners, and difficulties for local authorities in balancing tourism growth with the need to protect housing stability. Current laws, such as the Strata Titles Act 1985 and the Town and Country Planning Act 1976, do not adequately address the unique challenges posed by STRs, leaving significant gaps in governance and oversight.

Given these growing challenges, there is an urgent need to examine the multifaceted impacts of STRs on Malaysia's urban housing markets and to develop informed, context-specific policy responses. This research aims to contribute to that effort by providing an in-depth analysis of the effects of STRs on housing affordability, community stability, and regulatory frameworks in urban Malaysia.

II. LITERATURE REVIEW

Short-term rentals (STRs) have emerged as a disruptive force in urban housing markets. They are increasingly viewed as a form of housing assetization, distinct from gentrification or touristification (Gil, 2023). The expansion of STR platforms has been linked to rising housing prices and resident-tourist conflicts (Almeida et al., 2021). In Riyadh, for instance, STR growth has led to a reduction in the supply of long-term rentals (Tahar Ledraa & Alarabi, 2024).

Malaysia is experiencing similar trends, particularly in urban centres like Kuala Lumpur, where housing affordability challenges are compounded by STR activities. Olanrewaju and Idrus (2019) identify structural contributors such as land allocation and regulatory barriers to affordable housing. Meanwhile, Ho, Low, Wee, and Choong (2019) found that short-term renters prioritise product attributes over price, indicating a shift in market behaviour due to STRs. Adamiak and Marjavaara (2023) warn that the profitability of STRs may drive landlords to exit the long-term rental market, thus exacerbating housing shortages.

Beyond housing affordability, STRs affect the social fabric of urban communities. In Malaysia, strata buildings common in high-density areas face increased tension due to issues of privacy, overcrowding, and disruption caused by short-term guests (Abdullah & Ramly, 2024). Muschter et al. (2021) observed mixed resident perceptions of STRs, indicating both benefits and nuisances.

Malaysia's Strata Management Act 2013 lacks explicit provisions for STR regulation, complicating governance efforts. Stojčić, Pechlaner, and Vulić (2024) note that STRs often foster closed migration circuits, which hinder local knowledge exchange and erode social capital. Monahan (2021) and Angel and Doganer (2020) argue that high turnover in STR properties diminishes neighbourhood cohesion and stability. Gurran and Phibbs (2017) emphasise the importance of regulatory strategies that account for community well-being alongside economic development.

STRs have contributed to the gentrification and financialization of urban real estate. While increased tourist activity can bring economic gains to neighbourhoods, Nieuwland and van Melik (2018) highlight how STRs disrupt conventional long-term rental markets. According to Bekkerman, Romero, and Romano (2021), STRs incentivise speculative real estate investment, while stricter regulations tend to reduce both STR listings and permit applications.

In Portugal, Jover and Cocola-Gant (2022) document how STRs accelerate housing financialization by drawing capital into tourism-focused real estate. However, the effects are not uniform: Garciaa et al. (2021) find that STRs may also depress housing prices in some areas due to negative externalities. Sadeghi (2023) and Overwater and Yorke-Smith (2021) report that STR-related gentrification leads to the displacement of long-term residents, especially in highly touristic areas.

Malaysia's regulatory framework for STRs is still in its infancy. Though local councils and strata management bodies have attempted to introduce rules, the lack of a unified national policy results in inconsistent enforcement and legal ambiguity (Geoffrey, Sulaiman, & Samad, 2024). Existing laws, such as the Strata Titles Act 1985 and the Town and Country Planning Act 1976, do not sufficiently address STR-specific concerns.

This fragmented approach creates enforcement difficulties and jurisdictional inconsistencies. Wong and Kwok (2024) highlight regulatory disparities across states, while Abdullah and Ramly (2024) note that planning permissions for STRs are sometimes unnecessary, depending on location. Public opinion emphasises the need for stronger safety and licensing regulations (Zyed, Yong, & Tedong, 2020). The absence of STR-specific laws has also enabled some operators to bypass taxes and safety compliance (Daud & Mat Isa, 2021).

Experts recommend implementing a standardised legal framework to manage STR activity, which would provide clarity and protection for hosts, guests, and communities alike (Geoffrey et al., 2024; Wong & Kwok, 2024).

III. OBJECTIVES

1. To assess the impact of short-term rentals (STRs) on housing affordability and availability in major urban areas of Malaysia.
2. To evaluate the influence of STRs on community stability and social cohesion, particularly in high-density residential developments.

To analyse the relationship between STR concentration and rental price trends using quantitative housing market data

IV. METHODOLOGY

This study adopts a quantitative research approach to examine the effects of short-term rentals (STRs) on urban housing markets in Malaysia. Specifically, the methodology is designed to address three key research objectives: (1) to assess the impact of STRs on housing affordability and availability, (2) to evaluate the

influence of STRs on community stability and social cohesion, and (3) to analyze the relationship between STR concentration and rental price trends in urban areas.

The study employs primary and secondary data sources to achieve these objectives. Primary data was collected through a structured survey distributed to residents and stakeholders in urban areas with significant STR activity, such as Kuala Lumpur, Penang, and Johor Bahru. The survey was targeted at three main respondent groups: long-term residents (including both tenants and homeowners), property owners who operate STRs, and real estate professionals such as property agents and building managers.

A. Questionnaire Survey

The survey consisted of both closed-ended and Likert-scale questions designed to capture perceptions and experiences related to housing affordability, rental price changes, the availability of long-term rental units, and the impact of STRs on neighbourhood cohesion and residential stability. Questions also explored personal experiences with STR-related disturbances and attitudes toward STR regulations.

A stratified random sampling method was used to ensure representation across different housing types, income levels, and geographic locations. The sample size aimed for a minimum of 150 valid responses to ensure statistical significance and data reliability.

In addition to primary data, the study utilised secondary data sources to support and validate survey findings. These included rental price data and housing supply trends obtained from the National Property Information Centre (NAPIC) and Bank Negara Malaysia (BNM). Data on STR listings, such as the number, type, and location of listings, was gathered from major platforms including Airbnb, Agoda, and Booking.com. Demographic and socioeconomic data, including population density and urbanisation levels, were obtained from the Department of Statistics Malaysia (DOSM).

B. Data Analysis

The collected data was analysed using descriptive and inferential statistical techniques. Descriptive statistics, such as mean, median, and standard deviation, were used to summarise rental price levels and community perceptions. To explore the relationship between STR concentration and housing outcomes, correlation analysis was conducted. Additionally, multiple regression analysis was used to determine the extent to which STR activity influences rental price increases and housing availability, while controlling for variables such as location and income level. Cross-tabulations and frequency analysis were also applied to examine variations in community response across demographic groups.

All data was processed using Microsoft Excel and SPSS software to ensure accuracy and consistency in statistical analysis. The findings from this methodology provide a robust foundation for evaluating the broader effects of STRs on Malaysia’s urban housing landscape.

V. PREDICTED OUTCOMES

The research is anticipated to show a strong correlation between the concentration of STRs and reduced housing affordability and availability, particularly in urban centres such as Kuala Lumpur, Penang, and Johor Bahru. As more residential units are converted into short-term accommodations, the supply of long-term rental housing is likely to shrink, leading to increased rental prices and limited accessibility for local residents. This shift is expected to disproportionately affect low- and middle-income groups who rely on stable, affordable housing options in the city.

Secondly, the study is likely to uncover growing concerns regarding community stability and social cohesion, especially in high-density residential areas. Survey responses from residents are expected to reflect issues such as frequent disturbances, misuse of shared facilities, and the lack of accountability from transient occupants. These disruptions may contribute to a weakening of neighbourly relationships and a reduced sense of community within strata developments.

Thirdly, the findings are predicted to indicate that many stakeholders-especially long-term residents, building managers, and property professionals - believe the current regulatory landscape surrounding STRs is insufficient. Due to fragmented enforcement and unclear guidelines, there is likely to be a strong call for the introduction of a consistent and enforceable national framework that clearly defines the rights and responsibilities of STR operators.

In addition, the study is expected to provide valuable insights for urban policymakers and planners by highlighting the urgent need for data-driven, centralised regulations. The current legal gaps in Malaysia’s property and planning laws may be shown to hinder the ability of authorities to effectively balance tourism-driven economic benefits with the need for stable, affordable housing.

Lastly, this research is anticipated to contribute significantly to the academic and policy discourse on urban housing in Malaysia. By combining empirical data with stakeholder perspectives, the study aims to strengthen the foundation for future research and inform more equitable and sustainable policy decisions related to short-term rental accommodations.

CONCLUSION

The research highlights that while STRs offer clear economic advantages for property owners and support Malaysia's growing tourism sector, these benefits often come at the expense of housing affordability and residential stability for local communities. The current lack of a unified, enforceable regulatory framework has further complicated the situation, leading to inconsistent enforcement, legal ambiguities, and weakened governance across jurisdictions.

To move forward, it is essential for policymakers, urban planners, and real estate stakeholders to adopt a balanced and data-driven approach. Regulatory frameworks must evolve to safeguard long-term housing supply while allowing space for innovative, tourism-driven property use. This paper contributes to that process by providing empirical insights and stakeholder perspectives that can inform more sustainable and inclusive urban development policies.

In the end, addressing the STR phenomenon requires a collaborative effort to ensure that Malaysia's urban housing markets remain accessible, equitable, and resilient in the face of ongoing digital and economic transformations.

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STRATEGIES TO ENHANCED WORKPLACE SAFETY AND HEALTH IN CONSTRUCTION PROJECT: A PERSPECTIVE FROM QUANTITY SURVEYOR IN MALAYSIA

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ABSTRACT

This study explores occupational hazards, evaluates current safety protocols, and proposes strategies to improve workplace safety in Malaysia's construction sector. The research problem focuses on identifying hazards, assessing existing safety measures, and developing effective improvements. A comprehensive literature review examines industry-specific risks, regulatory frameworks, and best practices. Using qualitative methods, the study aims to mitigate risks and foster a safer work environment. The findings emphasize the need for a strong safety culture, enhanced training, and improved communication. By addressing key challenges, this research seeks to protect workers and create a safer, more sustainable construction industry in Malaysia.

Keywords: Construction Safety, Safety and Health, Construction Project, Quantity Surveyor

X. INTRODUCTION

The construction industry is one of the key contributors to Malaysia's economic growth, playing a significant role in national development. According to Khan et al. (2014), the sector is a major component of Malaysia's Gross Domestic Product (GDP), supporting infrastructure development and enhancing the living standards of the population. However, the industry is also recognised as one of the most hazardous sectors globally, with a high frequency of workplace accidents. Construction sites are complex environments that involve multiple stakeholders, heavy machinery, and dynamic activities, all of which contribute to increased safety risks (Othman et al., 2017).

Large-scale construction projects present even greater challenges due to their complexity, the number of workers involved, and the use of modern technologies and equipment (Xu et al., 2024). These factors make construction safety management more difficult and increase the likelihood of occupational hazards. Fathullah et al. (2021) emphasise that ensuring worker safety is a crucial responsibility for all parties involved. Unsafe working conditions can lead to delays, injuries, financial losses, and reputational damage to construction companies. Jamaluddin et al. (2015) note that accidents not only interrupt project timelines but also generate direct and indirect costs, affecting overall project success.

Despite various initiatives by government agencies such as the Department of Occupational Safety and Health (DOSH), Ministry of Health (MOH), SIRIM, and MIROS, the implementation of safety guidelines remains inconsistent across the industry. The existence of multiple, sometimes overlapping, guidelines has caused confusion and disagreements on best practices (Sukor et al., 2018). Additionally, reports by Malaysia's Social Security Organisation (SOCSO) show that construction-related commuting accidents and compensations have continued to rise, indicating the ongoing severity of safety issues in the sector.

The persistence of these challenges highlights the urgent need to identify effective strategies to improve workplace safety and health in Malaysian construction projects. This research aims to contribute to the reduction of hazards, injuries, and accidents, while promoting a safer working environment. By examining the role of Quantity Surveyors in safety practices, the study supports the broader objectives of enhancing project performance, reducing economic losses, and safeguarding worker welfare. Ultimately, improving safety measures will not only benefit the construction industry but also support national development and sustainable growth.

I. PROBLEM STATEMENT

The Malaysian construction industry continues to face serious safety and health challenges despite its vital role in national development. According to Ayob et al. (2018), SOCSO recorded an annual rate of 9.2 fatal work-related injuries per 100,000 workers and 2,822 occupational injuries, while DOSH reported 1,116 workplace accidents between 2011 and 2016—many of which occurred on construction sites. Although safety legislation exists and is enforced by the Department of Occupational Safety and Health (DOSH), safety performance remains poor across the sector (Othman et al., 2020).

A major issue lies in the lack of safety awareness and inadequate training among workers. Factors such as misuse of machinery, language barriers, unskilled labour, and fragmented subcontractor responsibilities contribute significantly to site accidents (Fathullah et al., 2021; Abdul Halim et al., 2020). Common hazards include falls from heights, insufficient PPE use, and non-compliance with safety procedures (Nadhim et al., 2016; Yi et al., 2022). These problems are worsened by weak enforcement, poor communication, and a lack of proactive safety culture. Although guidelines like OSHCIM 2017 and initiatives like the CIDB Green Card system have been introduced to improve safety performance, gaps remain in implementation, training, and monitoring (Mohd et al., 2020; Wong et al., 2023). New technologies such as drones for site surveillance and regular safety training have been recommended, yet adoption is inconsistent (Syed Zakaria et al., 2021; Albarkani & Shafii, 2021).

These ongoing issues highlight the need for a more strategic and collaborative approach to improve construction safety. This study addresses these concerns by exploring key hazards, evaluating current safety practices, and analysing strategies to enhance safety performance in the Malaysian construction sector, particularly from a Quantity Surveyor's perspective. As Quantity Surveyors are involved in cost planning, contract documentation, and monitoring preliminaries, their role is crucial in ensuring that safety requirements are properly budgeted, specified, and implemented throughout the project lifecycle.

II. LITERATURE REVIEW

Occupational hazards in the construction industry are widely acknowledged due to the sector's inherently dangerous nature and complex working conditions. According to Arshad et al. (2023), the construction industry ranks among the most hazardous, with frequent injuries and fatal accidents. Arifin et al. (2023) define a hazard as a condition that has the potential to cause harm, highlighting the importance of early risk identification and control. Safety compliance, as noted by Zhao and Yan (2023), involves strict adherence to procedures, including the proper use of personal protective equipment (PPE). Babalola et al. (2023) found that the construction sector experiences a fatality rate 3.5 times higher than other industries, making safety a critical concern. As Korkmaz and Park (2018) assert, the industry's economic contributions should not overshadow the responsibility to ensure worker safety. These definitions collectively underline the urgent need for improved safety standards and consistent compliance in the Malaysian construction sector.

A. Prevalent Occupational Hazard

The Malaysian construction industry faces a range of occupational hazards that continue to threaten worker safety and health. Among the most critical is the improper use of personal protective equipment (PPE), which remains a common issue across many project sites. Workers frequently neglect or misuse safety gear such as helmets, gloves, and harnesses—particularly during high-risk activities like working at height or operating machinery. This negligence significantly increases the likelihood of serious accidents and injuries (Arifin et al., 2023; Yi et al., 2022).

Table 1.0 Prevalent Occupational Hazard

No	Identify prevalent occupational hazards in the Malaysia Construction Project / Author	(Waqar et al., 2023)	(Arifin et al., 2023)	(Fathullah et al., 2021)	(Sukadarin & Zakaria, 2022)	(Abas, 2021)	(Samad et al., 2023)	(Abdul Halim et al., 2020)	(Ali, 2010)	(Hamid et al., 2019)	(Yi et al., 2022)	(Ranasinghe et al., 2023)	(Junia et al., 2024)	(Yang et al., 2023)	(Marchelli et al., 2023)	(Rey et al., 2021)	(Kim et al., 2016)	(Li et al., 2022)	(Cheung et al., 2018)	(Panmuvatvanich et al., 2020)	(Trask & Linderoth, 2023)	Times referred
1	Noise	/		/		/			/		/	/			/							7
2	Electrical hazard	/		/	/	/	/	/		/			/				/	/			/	11
3	Dust and debris	/							/	/	/	/		/	/							7
4	Chemical Gas leakage	/	/		/	/		/							/	/			/			8
5	Oxygen deficiency	/	/																			2
6	Sunstroke				/																	1
7	Poor project safety management	/								/	/			/			/	/		/	/	8
8	Mechanical hazard		/	/			/	/	/				/		/	/		/		/	/	11
9	Improper use of personal protective equipment		/	/	/	/	/	/	/	/	/	/				/	/				/	13
10	Explosion						/						/	/								3

In addition to PPE-related concerns, electrical and mechanical hazards are prominent threats on construction sites. Electrical risks arise from exposed wiring, faulty installations, and unsafe handling of tools, often leading to shocks, burns, or electrocution (Waqar et al., 2023; Kim et al., 2016). Mechanical hazards, on the other hand, are linked to the use of heavy equipment and machinery. Accidents frequently occur due to inadequate maintenance or untrained operators, resulting in crush injuries, falls, or even amputations (Samad et al., 2023). Furthermore, chemical gas leakage presents serious health risks when hazardous substances are improperly stored or handled. Such exposure can lead to respiratory problems or, in severe cases, explosions (Albarkani & Shafii, 2021; Arifin et al., 2023).

Overall, the persistence of these hazards highlights the urgent need for more effective safety enforcement, comprehensive training, and proactive hazard mitigation. Addressing these core issues—particularly through stricter PPE compliance, electrical and mechanical risk control, and improved chemical safety—will play a vital role in reducing accidents and ensuring a safer construction environment in Malaysia.

B. Current Safety Protocols and Procedures

To ensure safer working environments in construction, Malaysia has implemented several critical safety frameworks. The cornerstone of these is the Occupational Safety and Health Act 1994 (OSHA 1994), which mandates that employers are responsible for providing a workplace that is safe and free from health hazards. This act establishes the legal obligations of all parties involved in construction activities, creating a baseline for industry-wide safety standards (Othman et al., 2017; Wahab et al., 2023).

Table 2.0 Current Safety Protocols and Procedures

No	Author / To determine the current safety protocols and procedures employed in the Malaysia Construction Project	(Yi et al., 2022)	(Othman et al., 2017)	(Goh Pui Teck et al., 2015)	(Abdull Rahman, et al., 2022)	(Ahmad et al., 2018)	(Wahab et al., 2023)	(Ismail et al., 2021)	(Wong et al., 2023)	(Mohd et al., 2020)	(Ismail & Othman, 2021)	(Phinias, 2023)	(Osorio-Sandoval et al., 2023)	(Zhou et al., 2023)	(Albarkani & Shafii, 2021)	(Loganathan et al., 2020)	(Zahar, 2020)	(Hussain et al., 2023)	(Rohani et al., 2020)	(Hassan et al., 2021)	(Shaari et al., 2022)	Times referred
1	Occupational safety and health act 1994	/		/				/	/		/									/	/	7
2	CIDB Green card programme						/		/						/							4
3	Workmen compensation insurance														/		/					2
4	Occupational Safety and Health in Construction Industry (Management) OSHCIM 2017							/		/								/	/			4
5	Factory and machinery act 1967		/					/			/									/	/	5
6	Safe management measure				/				/			/	/									4
7	Standard operating procedure				/				/						/							3
8	Risk management		/	/		/						/	/	/								6
9	SOCSO						/									/	/					3
10	Toolbox meeting	/										/			/							3

In support of OSHA, the Factory and Machinery Act 1967 regulates the operation, inspection, and maintenance of machinery used on construction sites. It serves as a key reference for ensuring mechanical safety and preventing equipment-related accidents (Ahmad et al., 2018; Hussain et al., 2023). Complementing these legislative measures, risk management has become a vital component of safety planning. It involves systematically identifying potential hazards, assessing their severity, and implementing controls to mitigate risks before they lead to incidents (Yi et al., 2022; Zhou et al., 2023).

Additionally, the CIDB Green Card Programme plays a practical role in safety enforcement. This initiative requires construction workers to attend safety training and obtain certification before entering a worksite. The card functions as proof of basic safety knowledge and helps ensure that workers understand and comply with site safety rules (Wong et al., 2023; Albarkani & Shafii, 2021). Together, these protocols form the backbone of Malaysia's construction safety strategy. They establish clear responsibilities, promote proactive risk mitigation, and reinforce a safety-first culture across all levels of project execution.

C. Strategies for Enhancing Workplace Safety

Improving safety in the Malaysian construction sector requires proactive, well-structured strategies. One of the most effective methods is high engagement site safety training, which equips workers with the skills and

awareness needed to identify and manage on-site risks. This training model promotes behavioural change, strengthens the safety culture, and helps reduce accident rates, especially when delivered regularly (Zulkeflee et al., 2022; Junjia et al., 2024).

Table 3.0 Strategies Enhancing Workplace Safety

No	Strategies enhancing workplace safety and health in the Malaysia Construction Project / Author	(Belayutham & Che Ibrahim, 2019)	(Che Mat et al., 2021)	(Musarat et al., 2022)	(Zulkeflee et al., 2022)	(Kukoyi & Adebowale, 2021)	(Musarat et al., 2022)	(Mian et al., 2021)	(Yap et al., 2022)	(Yap et al., 2022)	(Mohammad & Hadikusumo, 2019)	(Chen et al., 2024)	(Okonkwo et al., 2023)	(Ranasinghe et al., 2023)	(Luo et al., 2023)	(Waqar et al., 2023)	(Tan et al., 2023)	(Buniya et al., 2021)	(Moshood et al., 2020)	(Trask & Linderoth, 2023)	(Rey et al., 2021)	(Junjia et al., 2024)	Times referred
1	IoT						/		/	/						/							2
2	Occupational Safety and health workshop	/						/						/			/	/				/	8
3	Pre -construction safety planning		/																		/	/	3
4	Risk management																/		/		/	/	6
5	High Engagement Site Safety Training			/	/	/				/	/		/	/	/	/	/	/		/		/	13
6	Robotic and Automation		/	/			/		/	/		/	/		/	/				/	/		7
7	Building Information Modelling		/	/			/		/	/										/		/	4
8	Invest resources in safety		/		/	/			/	/	/				/								4
9	Clear health and safety policies and regulation					/		/										/					3
10	Site management system							/		/	/	/	/	/			/						7

Occupational safety and health workshops complement this by offering ongoing education on safety standards, legal updates, and best practices. These workshops also foster communication among site supervisors, contractors, and workers, creating a platform for sharing safety concerns and solutions (Belayutham & Che Ibrahim, 2019). In parallel, a site management system ensures that safety responsibilities are clearly assigned and consistently enforced. Strong site supervision, routine inspections, and proper documentation are essential in maintaining a safe and orderly work environment (Buniya et al., 2021; Tan et al., 2023).

Moreover, robotic and automation technologies offer innovative ways to reduce exposure to high-risk tasks. By automating dangerous or repetitive activities, construction sites can minimise human error and significantly lower the risk of injury (Musarat et al., 2022). These tools also improve precision and productivity, contributing to safer and more efficient project delivery. In summary, combining high-impact training, active site supervision, educational engagement, and smart technology integration can effectively address safety challenges in the construction industry. These strategies not only mitigate hazards but also promote long-term safety performance and sustainability.

III. RESEARCH AIM

The aim of this research is to contribute to the improvement of workplace safety and health in the Malaysian construction industry by identifying key hazards, evaluating current safety practices, and analysing effective strategies. This study seeks to support the elimination of occupational risks and promote a safer, more secure working environment. By focusing on the perspective of Quantity Surveyors, the research aims to highlight their role in safety planning and implementation, ultimately contributing to reduced accident rates, enhanced compliance, and the long-term sustainability of construction projects in Malaysia.

IV. RESEARCH SCOPE

This research focuses on workplace safety and health within the Malaysian construction industry, specifically from the perspective of Quantity Surveyors. The study investigates common occupational hazards on construction sites, evaluates existing safety protocols and procedures, and explores strategies for improving safety performance. It also examines the role of Quantity Surveyors in enhancing safety planning, compliance, and awareness across different construction phases. The study takes a nationwide approach, covering all of Malaysia rather than focusing on a specific region. This broader scope allows for a more comprehensive assessment of safety and health practices, resulting in a well-rounded understanding of their implementation throughout the country.

V. RESEARCH METHODOLOGY

This study adopts a quantitative research design to investigate strategies for enhancing workplace safety and health in Malaysian construction projects from the perspective of Quantity Surveyors. The methodology is structured into three main stages: Initial Stage, Intermediate Stage, and Final Stage, each serving a distinct purpose in guiding the research process systematically from conceptualisation to data analysis.

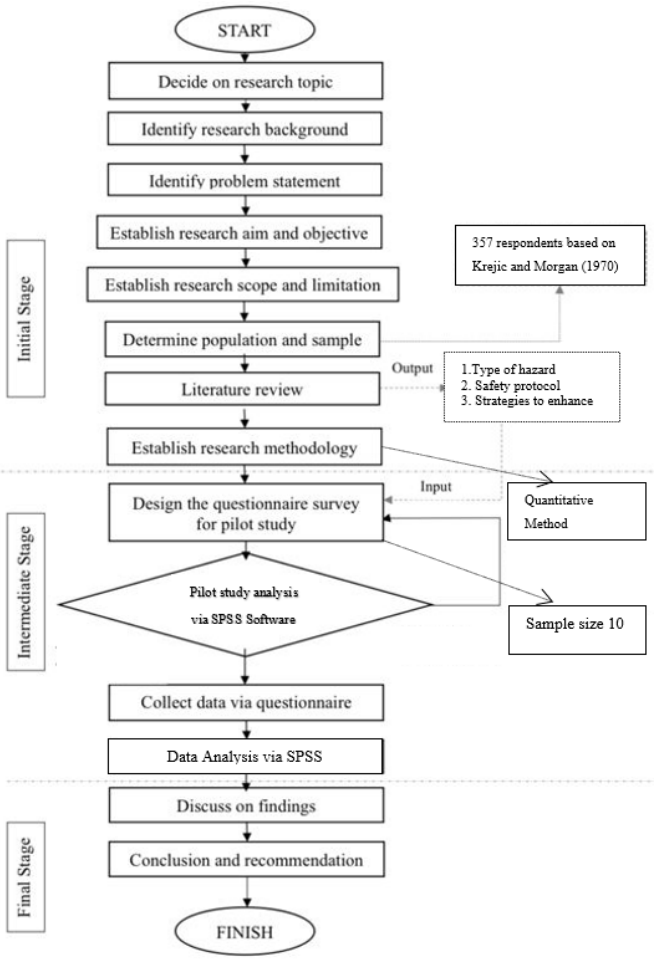


Figure 4.0 Research Design

D. Initial Stage

The research begins by selecting the topic related to workplace safety and health in the Malaysian construction industry, focusing on the role of Quantity Surveyors. This is followed by reviewing the background of the study and clearly defining the problem statement to justify the need for the research. Once the issue is established, the aim and objectives of the study are formulated to guide the direction of the research. The scope is then defined to cover construction projects across Malaysia, ensuring broad representation. The population is determined, and a sample size of 357 respondents is selected using the Krejcie and Morgan (1970) table. A comprehensive literature review is conducted to explore three key areas: types of occupational hazards, current safety protocols and procedures, and strategies to enhance safety performance. Based on these insights, the research methodology is established, adopting a quantitative approach for data collection and analysis.

E. Intermediate Stage

During the intermediate stage, a structured questionnaire is developed based on the findings of the literature review and aligned with the research objectives. A pilot study involving 10 respondents working in the construction sector is conducted to evaluate the clarity, relevance, and reliability of the questionnaire. This sample size is consistent with established guidance for pilot research, where small samples are often used due to resource constraints and the preliminary nature of the investigation. According to Lowe (2019), a cautious approach with a small pilot sample enables researchers to test instruments effectively, refine their methodology, and assess feasibility before proceeding to full-scale data collection. The responses from this stage are analysed using SPSS software, allowing for improvements to the survey tool and ensuring its validity. This step is crucial

for enhancing the quality and consistency of the final questionnaire, forming a solid foundation for subsequent large-scale analysis.

F. Final Stage

The final stage involves distributing the validated questionnaire to 357 Quantity Surveyors across Malaysia, based on the Krejcie and Morgan (1970) sample size table. Quantity Surveyors were selected because of their influence in planning, budgeting, and administrating safety provisions in the early stages of construction projects. Data is collected through both online and offline methods and analysed using SPSS, with mean values used to identify patterns in workplace hazards, current safety practices, and improvement strategies. These mean scores are then compared with findings from the literature to determine which strategies are most effective and widely recognised, aligning academic insight with practical industry needs. This helps to identify cost-effective and proactive safety solutions from a QS perspective that can be integrated into early project planning.

VI. EXPECTED OUTCOME OF THE RESEARCH

This research is expected to generate several significant outcomes that contribute to the improvement of workplace safety and health within the Malaysian construction industry. One of the primary outcomes is the identification and classification of the most prevalent occupational hazards encountered on construction sites. This will provide industry professionals, particularly quantity surveyors, with a clearer understanding of high-risk areas that require urgent attention, enabling them to better anticipate, manage, and mitigate on-site hazards through cost planning and contract provisions. Additionally, the study will assess the effectiveness of existing safety protocols and procedures implemented within the industry. By identifying their strengths and limitations, the research aims to support construction firms, regulatory bodies, and safety practitioners in enhancing current practices. Importantly, the study emphasizes the role of quantity surveyors in integrating safety considerations during the early stages of a project, such as in the preparation of the Bill of Quantities, risk allocation in tender documents, and financial allowances for safety measures.

Finally, the research is anticipated to offer evidence-based strategies for enhancing workplace safety, with a particular focus on the planning and monitoring roles of quantity surveyors. The findings will inform strategic decisions related to safety training, policy development, and cross-disciplinary collaboration among project stakeholders. Ultimately, the outcomes are expected to contribute to a safer work environment, strengthen industry practices, and support the sustainable advancement of Malaysia’s construction sector.

CONCLUSION

This study explored key occupational hazards, current safety protocols, and strategies to enhance workplace safety and health in the Malaysian construction industry, with emphasis on the quantity surveyor’s role. As professionals responsible for cost planning, contract documentation, and project coordination, quantity surveyors significantly influence how safety measures are budgeted, specified, and enforced. Their early involvement allows safety considerations to be embedded from the planning stage, ensuring better compliance and risk mitigation. The findings reinforce the need for a more integrated and proactive approach, positioning quantity surveyors as key contributors to promoting a safer and more sustainable construction environment.

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REVITALIZING THE MELAKA GATEWAY PROJECT: KEY APPROACHES AND STRATEGIC FACTORS FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

The Melaka Gateway project, a large-scale land reclamation initiative in Malaysia, exemplifies the complexities of balancing economic development with socio-cultural and ecological sustainability. Initially envisioned as a Belt and Road Initiative (BRI) flagship to transform Melaka into a global maritime hub, the project faced systemic challenges-including mismanagement, environmental degradation, cultural erosion, and community marginalization-leading to its termination in 2020 and scaled-down revival in 2023. Through a narrative review methodology, this study synthesizes academic, governmental, and community perspectives to analyse the project's failures and propose revitalization strategies. Key challenges include the disruption of coastal ecosystems, threats to the Kristang community's cultural heritage, reliance on unstable foreign investment, and outdated environmental assessments. To address these, the study identifies five strategic priorities: financial planning to stabilize funding, community engagement to restore trust, policy alignment with sustainability standards, rebranding to leverage Melaka's UNESCO heritage, and infrastructure connectivity to enhance tourism and trade. Findings underscore the necessity of participatory governance, adaptive frameworks, and climate-resilient practices to align modernization with cultural and ecological preservation. The Melaka Gateway's trajectory offers critical lessons for future land reclamation projects, advocating for holistic strategies that prioritize equity, transparency, and long-term sustainability over short-term economic gains.

Keywords: Land Reclamation, Melaka Gateway, Revitalization, Sustainable Development, Government Support

I. INTRODUCTION

Land reclamation is the process of creating new land by transforming water bodies such as seas, rivers, lakes, or wetlands, or improving degraded land to make it suitable for human use. This is achieved through methods like filling areas with soil or sand, draining waterlogged land, or stabilizing the terrain. It serves purposes such as urban development, agriculture, industrial expansion, and infrastructure creation. In Malaysia, land reclamation is a common solution to address the growing demand for urban and industrial spaces in densely populated or strategic coastal regions. The country's rapid urbanization and economic expansion have made land reclamation essential for meeting housing, tourism, and industrial needs. Land reclamation in Malaysia has been a key strategy for urban growth and economic development, particularly in coastal cities like Penang, Johor, and Melaka. In Penang, projects such as artificial islands for residential and commercial use have raised environmental concerns, including impacts on marine ecosystems and local fishing industries (Barro, 2020). Similarly, Johor's Forest City development has faced criticism for destroying mangroves and coastal habitats despite its economic promises (Marcel & Williams, 2016). Melaka, a historically significant port city with a rich cultural heritage shaped by Portuguese, Dutch, and British colonization, began land reclamation in the 1980s to support urbanization, tourism, and real estate development (Barro, 2020). The ambitious Melaka Gateway project, launched in 2014, aims to create artificial islands for tourism, international business, and residential complexes, but has sparked concerns over environmental and social impacts, including marine biodiversity loss and disruption to local fishing communities (Marcel & Williams, 2016). Balancing modern development with the preservation of Melaka's cultural heritage remains a critical challenge (Centre, 2008).

II. MELAKA GATEWAY

One of the largest and most ambitious projects in recent years has been the Melaka Gateway project, launched

in 2014. This project involves reclaiming land to create artificial islands intended for tourism, international business, and residential complexes, further expanding the coastline (Melaka Gateway, 2023). The project is expected to transform Melaka into a major international destination, attracting global investors and tourists. However, while the project promises economic growth, it also raises concerns about its environmental and social impacts. Critics argue that large-scale reclamation could lead to the loss of marine biodiversity and affect local fishing communities (Marcel & Williams, 2016). Figure 1.0 shows the visual map of Melaka Gateway's four islands, which are the early concept of this project.



Figure 1.0 Visual Map of Melaka Gateway's four island
Source: BRI Monitor Melaka Gateway 2023

The Melaka Gateway project is an ambitious land reclamation initiative aimed at transforming the coastal landscape of Melaka, Malaysia, into a vibrant maritime hub. Initially launched in 2014, the project was envisioned to include the development of four artificial islands, two of which would be reclaimed from the sea, alongside a range of facilities such as a deep-sea port, cruise terminal, financial centre, and maritime industrial park. The project was intended to reinstate Melaka's historical significance as a key trading port while stimulating economic growth in the region (BRI Monitor, 2023).

Despite its grand vision and initial backing from significant Chinese investments as part of the Belt and Road Initiative (BRI), the Melaka Gateway has faced numerous challenges and controversies. The project's timeline has been plagued by delays and legal disputes, leading to its termination in November 2020 due to the developer's failure to meet critical deadlines and infrastructural prerequisites (Arnez, 2020). Following its cancellation, the project experienced a revival in 2023. This decision came after an amicable resolution between KAJD and the Melaka state government. However, the revived project has been scaled down in ambition, which is Melaka Internation Cruise Terminal compared to its original plans (Tham, 2024). Environmental concerns remain prominent, with local communities expressing fears about the ecological impact of reclamation activities on their livelihoods and the surrounding marine environment (Arnez, 2020).

III. METHODOLOGY

This study employs a narrative review methodology (Ferrari, 2015; Greenhalgh et al., 2018) to holistically analyze the challenges and revitalization strategies of the Melaka Gateway project, integrating diverse sources such as academic articles, government reports, NGO publications, and local news. A purposive search across databases (Scopus, Web of Science, Google Scholar) and grey literature used keywords like Melaka Gateway, land reclamation, and cultural heritage to capture socio-economic, environmental, and cultural dynamics, supplemented by manual reference-list searches. Sources were prioritized for relevance to the project's multi-dimensional impacts, including critiques of governance, ecological trade-offs, and community-led advocacy. Thematic analysis (Baumeister & Leary, 1997) identified recurring issues such as foreign

investment dependency, outdated environmental assessments, and threats to Kristang cultural heritage, synthesizing insights from case studies (e.g., Johor's Forest City) to contextualize revitalization strategies. While the narrative approach risks subjectivity, findings were triangulated across academic, governmental, and community perspectives to balance rigor with interpretive depth, enabling a multidisciplinary critique of the project's failures and pathways for sustainable recovery.

IV. FACTORS CONTRIBUTING TO THE FAILURE OF THE MELAKA GATEWAY

The Melaka Gateway project, a large-scale land reclamation initiative in Malaysia, exemplifies the complex challenges of balancing ambitious development goals with socio-cultural and ecological sustainability. Designed to transform Melaka into a global maritime and tourism hub, the project has faced significant setbacks due to its profound impacts on local communities, economies, and ecosystems. Socially, it disrupted traditional fishing livelihoods and marginalized minority groups like the Kristang community, whose cultural identity is deeply rooted in coastal heritage. Economically, reliance on foreign investment and mismanagement led to delays, oversupply of luxury infrastructure, and unrealized benefits. Environmentally, large-scale coastal destruction threatened critical habitats like mangroves and coral reefs, while outdated assessments ignored climate vulnerabilities. Culturally, the project risked erasing Melaka's UNESCO-recognized heritage by prioritizing commercialization over preservation. Together, these intertwined issues such as social inequity, financial instability, ecological harm, and cultural erosion highlight the pitfalls of prioritizing rapid modernization over holistic, inclusive development.

A. Social Aspect

The Melaka Gateway project's social challenges stemmed from its profound disruption to local communities and cultural heritage. Land reclamation and sedimentation severely degraded marine ecosystems, slashing fish stocks and crippling the livelihoods of fishing communities in Bandar Hilir and Duyong, with fishermen reporting drastic declines in catches due to water turbidity and siltation (IDEAS, 2022). Inadequate infrastructure, such as the incomplete 750-meter channel (only 200 meters constructed), exacerbated flooding and blocked access to fishing grounds, leaving fishermen struggling with damaged equipment from debris and dwindling incomes (Arnez, 2020; IDEAS, 2022). The Kristang community, whose identity is deeply intertwined with Melaka's coastal heritage, faced existential threats as reclamation eroded maritime traditions central to their festivals and daily lives, sparking symbolic protests like lying in coffins to signify the "death" of their way of life (Arnez, 2020). Grassroots activism, including the "Fresh Air, Clean Water" initiative, amplified opposition by linking environmental restoration (e.g., mangrove rehabilitation) to cultural survival (Arnez, 2020; IDEAS, 2022). Marginalization of minority voices in decision-making fueled distrust, as development priorities appeared to favor commercial interests over local welfare. Additionally, the project's encroachment on landscapes tied to Melaka's UNESCO World Heritage status risked erasing tangible and intangible historical legacies, drawing scrutiny from global preservation advocates (New Mandala, 2022). These intersecting social grievances—livelihood loss, cultural erosion, activist resistance, and heritage threats to bring out the undermined public trust, galvanized opposition, and ultimately contributed to the project's collapse.

B. Economic Aspect

The Melaka Gateway project's economic viability has been jeopardized by its heavy reliance on foreign investment, particularly from Chinese stakeholders under the Belt and Road Initiative (BRI), coupled with mismanagement instability. Initially budgeted at RM43 billion, delays and funding complications led to only one of three planned islands being completed by late 2023, undermining investor confidence (BRI Monitor, 2023). Projected benefits, including 45,000 jobs and 2.5 million annual tourists, failed to materialize due to oversupply in luxury real estate, weak demand for high-end tourism infrastructure, and global economic uncertainties. Local communities, especially fishermen, suffered economic losses as reclamation degraded fish stocks and coastal ecosystems, destabilizing livelihoods reliant on fishing and small businesses (The Vibes, 2022). Rising construction costs, delayed returns, and skepticism about long-term demand further eroded the project's financial sustainability, raising doubts about its ability to deliver promised economic gains.

C. Environmental Aspect

The Melaka Gateway project has sparked significant environmental concerns due to its large-scale reclamation of 10,117 hectares of coastline, threatening critical ecosystems such as mangroves, coral reefs, and seagrass beds that sustain marine biodiversity, local fisheries, and coastal resilience (Yeong, 2022). Reclamation

activities have already led to declining fish populations, jeopardizing the livelihoods and cultural heritage of fishing communities tied to these ecosystems for generations (Yeong, 2022; edgeinvest, 2023). Critics highlight outdated environmental impact assessments (EIAs), including reliance on a 1997 EIA that failed to address current climate vulnerabilities and ecological pressures, as well as a lack of transparent social impact evaluations (BRI Monitor, 2023; Yeong, 2022). The destruction of habitats like mangroves, key for carbon sequestration, flood protection, and fish breeding and risks irreversible ecological damage, compounded by inadequate mitigation plans. These oversights, alongside insufficient stakeholder consultation, have fueled demands for updated, comprehensive assessments and sustainable alternatives to balance development with environmental and cultural preservation.

D. Culture Heritage Aspect

Melaka Gateway project threatens the cultural heritage of the Kristang community, descendants of Portuguese settlers whose identity is deeply tied to maritime traditions and coastal livelihoods. Reclamation activities have restricted access to traditional fishing grounds, disrupting not only their economic sustenance but also centuries-old cultural practices rooted in proximity to the sea, risking the erosion of ancestral ties (The Vibes, 2022). The physical transformation of Melaka's coastline further endangers symbolic connections to the sea, central to Kristang heritage, with critics warning that commodifying these landscapes for tourism risks reducing their culture to a superficial attraction (Shepard, 2020; Aliran Admin, 2024). As a UNESCO World Heritage site, Melaka's authenticity is at stake, as large-scale development prioritizes commercial interests over preservation, potentially jeopardizing its international status and diluting its historical character (Aliran Admin, 2024; BRI Monitor, 2023). The Kristang's marginalization reflects broader challenges faced by Malaysia's minorities, where rapid urbanization threatens intangible heritage like language, oral traditions, and communal practices. Advocates call for inclusive policies, cultural impact assessments, and community collaboration to safeguard heritage amid development (Arnez 2020; IDEAS, 2022).

V. STRATEGIES FOR REVITALIZATION ON MELAKA GATEWAY FOR ENSURE SUCCESSFUL COMPLETION WITH NEW DIRECTION

The Melaka Gateway project, launched with ambitious aspirations as a flagship venture under China's Belt and Road Initiative (BRI), epitomizes the complexities and challenges inherent in large-scale international infrastructure development. Conceived as a multi-billion-dollar integrated port, commercial, and tourism hub, the project initially garnered attention for its potential to transform Malaysia's historical city of Melaka into a global maritime and economic nexus. However, its trajectory has been marred by protracted delays, legal entanglements, and environmental controversies, culminating in its abrupt termination in 2020 due to the developer's failure to fulfill contractual obligations. Despite this setback, the project resurfaced in 2023 through a negotiated settlement between KAJD Development and the Melaka state government, albeit in a significantly scaled-down form—the Melaka International Cruise Terminal. While this revival signals a tempered resurgence, persistent environmental concerns and skepticism from local communities underscore unresolved tensions between developmental ambitions and ecological sustainability. This introduction examines the project's turbulent journey, exploring how geopolitical aspirations, governance challenges, and socio-environmental trade-offs have shaped its evolution from a BRI symbol of prosperity to a cautionary tale of modern infrastructure diplomacy. Five strategies will apply to the revitalization on Melaka Gateway for ensure successful completion with new direction, with are financial planning, community engagement and support, government policy and guideline, rebranding campaign and infrastructure connectivity.

A. Financial Planning

Financial planning is essential for the successful execution of development projects, providing a roadmap for decision-making and resource allocation. It enables accurate cost estimation, budget development, and identification of financial risks, reducing the likelihood of budget overruns (Planful, 2022). Effective financial planning enhances transparency and accountability, fostering trust among stakeholders and securing necessary funding (Planful, 2022). It also supports risk management by identifying potential financial pitfalls early and developing contingency plans, ensuring adaptability to changing circumstances. Furthermore, financial planning optimizes resource allocation, maintaining operational efficiency and maximizing returns on investment. By prioritizing financial planning, project leaders can navigate challenges effectively, achieve objectives, and ensure long-term success.

B. Community Engagement and Support

Community engagement and support are vital for the success of development projects, fostering a sense of ownership and public acceptance while building trust and collaboration (Angela, 2024). Engaging local

communities provides valuable insights into their environment, culture, and needs, enabling project managers to address potential challenges early and align solutions with local aspirations. This proactive approach reduces opposition and enhances sustainability, while ensuring compliance with regulatory requirements that mandate community consultation (UNICEF SBC Guidance, 2024). Effective engagement also improves the reputation of developers by demonstrating social responsibility and fostering goodwill, which is increasingly important in a competitive landscape. By prioritizing meaningful engagement strategies, developers can create positive impacts that resonate with the communities they serve.

C. Government Policy and Guideline

Government policies, guidelines, and Environmental Impact Assessments (EIAs) are critical for ensuring the success and sustainability of development projects. They establish a framework for legal compliance, helping projects meet safety, environmental, and social standards while avoiding legal disputes and financial losses. EIAs promote environmental protection by identifying and mitigating ecological risks, aligning projects with global sustainability goals (EcoOnline, 2024). These frameworks foster stakeholder confidence by promoting transparency and accountability, encouraging public and private support (Soofa Digital, 2024). Additionally, they minimize risks and conflicts by addressing social and environmental issues early, ensuring sustainable development that benefits communities without compromising future resources (UNICEF SBC Guidance, 2024). Aligning with regulatory requirements also enhances long-term viability by reducing operational costs and avoiding reputational damage (PricewaterhouseCoopers, 2022).

D. Rebranding Campaign

The rebranding campaign for the Melaka Gateway Project is a key strategy to revitalize the area and position it as a premier tourist destination. Leveraging Melaka's UNESCO World Heritage status and historical significance, the campaign highlights unique attractions like a floating restaurant inspired by Cheng Ho's treasure ship and cultural events such as festivals and markets (edgeinvest, 2023). A central component is the Melaka International Cruise Terminal (MICT), expected to attract 3.5 million tourists annually, boosting local tourism and the economy (edgeinvest, 2023). Sustainability initiatives aligned with ESG principles will promote eco-friendly practices, while a comprehensive marketing strategy—including digital campaigns and international partnerships—will raise global awareness (edgeinvest, 2023). Supported by strong government backing and renewed investor confidence, KAJ Development Sdn Bhd (KAJD) aims to transform the Melaka Gateway Project into a thriving hub, delivering significant economic and cultural benefits to the region.

E. Infrastructure Connectivity

Infrastructure connectivity is a cornerstone of the Melaka Gateway Project, designed to position the region as a hub for tourism, trade, and commerce. Central to this effort is the Melaka International Cruise Terminal (MICT), which will accommodate the world's largest cruise ships and handle approximately 3.5 million tourists annually by 2026 (Tham, 2024). Improved road access and public transportation will ensure seamless connectivity between the terminal and key attractions, such as UNESCO World Heritage Sites. The project also integrates smart city technologies, including city-wide Wi-Fi and fiber optic networks, to support digital services like e-education and e-health, promoting sustainability and efficiency (Melaka Gateway, 2023). Additionally, plans to upgrade Melaka's airport and establish direct flights to destinations like Guangzhou aim to create a multi-modal transport system, enhancing accessibility for tourists and businesses while driving economic growth and regional development (Clark, 2023).

CONCLUSION

The Melaka Gateway project's turbulent journey, from its ambitious inception under the Belt and Road Initiative (BRI) to its eventual downsizing into the Melaka International Cruise Terminal, erves as a critical case study in balancing modernization with socio-ecological sustainability. Initially envisioned as a catalyst for economic transformation, the project faltered due to systemic failures: overdependence on foreign investment, environmental negligence, marginalization of local communities, and disregard for Melaka's UNESCO-recognized cultural heritage. Its 2020 termination and 2023 revival underscore the pitfalls of prioritizing rapid development over participatory governance and adaptive planning. However, the project's scaled-down resurgence offers a roadmap for revitalization. Strategic financial planning, inclusive community engagement, stringent adherence to updated environmental policies, and infrastructure enhancements like the Melaka International Cruise Terminal demonstrate how recalibrating priorities can align economic goals with ecological and cultural preservation. Rebranding efforts that leverage Melaka's historical legacy, paired with smart-city technologies and multi-modal connectivity, further illustrate pathways to sustainable success.

Ultimately, the project's evolution highlights the necessity of integrating dynamic stakeholder collaboration, climate-resilient frameworks, and cultural sensitivity into land reclamation initiatives. By learning from these lessons, policymakers and developers can transform underutilized or contested reclaimed spaces into inclusive, adaptive assets that harmonize economic ambition with the needs of people and ecosystems.

ACKNOWLEDGMENT

I extend my heartfelt gratitude to my parents for their unwavering support and belief in me. Special thanks to my supervisor, Dr. Nur, for her invaluable guidance and expertise, and to my faculty for providing resources and opportunities for my growth. I am deeply grateful to my friends, especially my close friends for their constant encouragement. Finally, I acknowledge all contributors whose support made this research possible.

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CIRCULAR ECONOMY POLICIES IN MALAYSIA'S CONSTRUCTION INDUSTRY: A STUDY OF OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Malaysia's construction industry is a critical driver of economic growth but also a major contributor to environmental degradation due to high resource consumption and substantial waste generation. Considering challenges faced by linear economy, the concept and adoption of circular economy (CE) provides a more comprehensive and transformative framework that presents more valuable opportunities for the construction sector to address its sustainability challenges. This research aims to promote the adoption of CE practices within Malaysia's construction industry by: (1) examining the opportunities, existing CE policies and frameworks in Malaysia's construction industry, (2) examining challenges to the implementation of CE principles in construction projects and (3) proposing CE policies based on global frameworks and potential way forwards recommendations to enhance CE adoption. A quantitative research approach was employed; utilising questionnaire surveys distributed to all professionals in the construction industry. Descriptive statistics are used to organised and summarised collected data. The findings are expected to reveal significant challenges in adopting CE and ways to solve based on CE implementation in other countries. With the growing importance of Environmental, Social and Governance (ESG), this research is expected to offer practical recommendations to develop a comprehensive CE framework for the greater adoption of CE practices in Malaysia's construction industry to align with Sustainable Development Goal 11 and 12.

Keywords: Circular Economy, Construction Waste, Sustainable, Construction Project

I. INTRODUCTION

The construction industry is a crucial contributor to Malaysia's economy whereby the construction market is projected to reach USD 41. 85 billion in 2025, with an expected 30% growth in 2030 at a compound annual growth rate of 8.55% (Construction Industry Development Board (CIDB Malaysia), 2025). However, its activities have substantial environmental impacts, accounting for 40% of raw material consumption and 39% of global carbon emissions, with 11% attributed to the production of materials and products (Dsilva, Zarmukhambetova, and Locke, 2023). In Malaysia, the construction industry affects approximately 67.5% of ecosystems and 21% of natural resources (Yusof, Awang, and Iranmanesh, 2017). Moreover, an estimated 8 million tonnes of construction waste (CDW) are generated annually (Umar, Shafiq and Ahmad, 2021) and 35% of CDW produced are directed to landfills without further treatment (Menegaki and Damigos, 2018), raising concerns over environmental impact. Evidently, many industry players still follow a linear "take-make-consume-waste" model, where discarding materials is often cheaper and easier than sustainable waste management, resulting in significant resource depletion and environmental impact (Esa, Halog and Rigamonti, 2017).

II. TRANSITIONING TO THE CIRCULAR ECONOMY

The transition to a CE, which focuses on reusing products and optimising waste management, has become a national priority to tackle sustainability challenges. With the global waste recycling market valued at over $500 billion USD in 2021, and only 40% of construction waste currently recycled or reused (Cemex Ventures, 2022), there is significant potential for improvement and adoption in the Malaysia construction industry. However, there is currently a lack of comprehensive literature on the specific benefits and opportunities of CE practices within Malaysia's construction industry. Most existing studies focus primarily on waste reduction, rather than embracing a holistic CE approach. This gap is compounded by the absence of dedicated CE frameworks

tailored to the local context. Furthermore, current efforts to implement CE often fall short due to persistent challenges, including regulatory barriers, financial limitation, technological constraints and a lack of awareness among industry stakeholders (Ha, Khoo and Koo, 2023). These issues underscore the urgent need for further research and the development of effective policies and frameworks to support CE adoption in the industry.

III. CE APPROACHES IN THE BUILT ENVIRONMENT

3.1 Definition of CE

CE in the built environment shifts from linear practices to a system focused on retaining resource value. Cheshire (2019) highlights strategies like reuse, refurbishment, and recycling, supported by design principles such as disassembly and adaptability. The World Economic Forum (2023) outlines CE across three dimensions—circulation, efficiency, and utilization—predicting a 38% CO_2 reduction in building materials by 2050 through circular strategies. Leising et al. (2018) view buildings as material banks, integrating end-of-life planning to extend lifespans, while Pomponi and Moncaster (2017) emphasize a broader framework involving governance, economy, society, and technology to support system-wide circularity.

3.2 Benefits of CE

The adoption of CE strategies brings notable environmental and economic gains, supported by both global models and local efforts. In Europe, improved material and energy efficiency could cut carbon emissions, raise GDP by over 2%, and create jobs (Wijkman & Skanberg, 2017). Locally, recycled aggregates help reduce landfill waste and emissions by up to 90% (Neupane et al., 2025), while plastic substitution cuts carbon by 28% and water use by 48% (Assaf & Abu Abdo, 2022). Projects like Tanarimba showcase sustainable design using local materials, preserving forest areas and achieving profitability in four years (Chan, Lee & Lee, 2014). In the Netherlands, CE could add €7.3 billion and 54,000 jobs annually (Rood & Hanemaaijer, 2017). Malaysia's growing use of Wood Plastic Composite (WPC), made from 70% biomass waste, presents strong potential for exports, GDP growth, and job creation (The Star, 2024).

3.3 Timeline of Solid Waste Policy Transition in Malaysia

The Malaysian Government has introduced several policies to improve construction waste management, culminating in the CE Blueprint for Solid Waste (2025–2035). While the blueprint lays a strong foundation through five strategic pillars—including legislation, digitalisation, infrastructure, and financial incentives—it still lacks a comprehensive framework for fully implementing CE in the construction industry. Most initiatives focus on household waste, with limited measures addressing construction and demolition waste (CDW). Key steps like the PAYT system and promotion of recycled aggregates exist but are insufficient, highlighting the need for a dedicated CE framework for the construction sector.

3.4 Challenges of Implementing CE in Malaysia Construction Industry

Despite its benefits, CE implementation in Malaysia's construction industry faces challenges due to the lack of a dedicated focus, making international best practices essential for guiding a structured transition.

3.4.1 Challenge 1: Regulatory and Legislative Constraints

Enforcement of sustainability initiatives in Malaysia's construction industry remains weak. Despite widespread promotion of the 3R concept, only 39.7% of contractors implement these practices, reflecting regulatory ambiguity and poor enforcement (Ng, Tan, and Seow, 2017). Studies have identified a lack of political will, ineffective governance, and weak legislative frameworks as key barriers to sustainability adoption (Shari and Soebarto, 2012).

3.4.1.1 Global Practices and Frameworks

3.4.1.1.1 Extended Producer Responsibilities (EPR)

EPR is a policy based on the Polluter Pays Principle, holding producers accountable for the environmental impact of their products throughout their lifecycle (KPKT, 2016). It supports CE by encouraging eco-friendly design and creating secondary material markets. Although Malaysia's CE Blueprint for Solid Waste (2025–2035) incorporates EPR, it focuses only on solid waste, while construction waste is addressed under the PAYT system. Adopting international EPR models could help Malaysia strengthen its legislation to ensure manufacturers, developers, and contractors take responsibility for recycling and proper disposal of construction materials.

3.4.1.1.2 Japan's Construction Material Recycling Law

Japan's law requires the sorting and recycling of construction materials such as concrete and asphalt to be processed and reused to reduce reliance on virgin materials (Global Environment Center, 2012). By requiring contractors to comply with these regulations for projects of a certain scale, the law prevents valuable resources from ending up in landfills and supports resource recovery (Global Environment Center, 2012). The law's impact is evident from the significant decrease in construction waste volume where the reuse/recycle/reduction ratio reached 97% by 2018 (Sumikura and Katsumi, 2022).

3.4.1.1.3 China's Urban Construction and Demolition Waste Management and mandatory usage of RA

The Urban CDW Management implement a charge system which impose penalties for non-compliance and requires a formal approval process for waste disposal (Wang et al., 2017), further strengthening regulatory oversight. These measures could inform Malaysia's approach to creating robust legislative tools to enforce CE principles while incentivizing adherence through penalties and cost-sharing mechanisms, ensuring industry-wide compliance. Additionally, China's policy mandates the use of RA in construction projects, such as requiring concrete below C25 to contain 15% RA, has proven successful in advancing CE goals (Yao, 2018).

3.4.2 Challenge 2: Financial Challenges

Financial challenges in adopting CE practices is largely due to the industry's fragmented structure and the dominance of smaller businesses with limited experience in sustainable methods (Mohd Ali et al., 2024). This is because sustainable materials and technologies are typically more expensive than conventional alternatives, making it difficult for designers and contractors with restricted budgets to adopt these practices. Moreover, larger developers are better positioned to adopt sustainable practices, as they can allocate resources effectively through proper planning and budgeting (Chan, Lee, and Lee, 2014).

3.4.2.1 Global Practices and Frameworks – Build Transformation Fund (BTF) by Singapore

The BTF by Singapore's Building and Construction Authority (BCA) is a national strategy that consolidates various support schemes to drive industry transformation, offering up to 70% co-funding for areas like Design for Manufacturing and Disassembly, digital delivery, green initiatives, innovation, and workforce upskilling (BCA, 2019; Singapore Institute of Architects, 2020). It makes innovation more accessible, especially for small-medium enterprises (Infocomm Media Development Authority, 2020), and provides indirect subsidies through training support (SIA, 2020), positioning BTF as a model Malaysia could adapt for strategic industry reform.

3.4.3 Challenge 3: Knowledge Gap and Limited Awareness

Survey data reveals that 75% of industry participants are unfamiliar with CE concepts, with 90% expressing a lack of readiness to adopt these practices within the next five years (Siew, 2019). This knowledge gap extends beyond the private sector, affecting government entities, designers, and contractors (Mohd Ali et al., 2024). As a result, resistance to CE implementation persists, with stakeholders lacking the technical expertise and practical understanding needed to integrate sustainable practices effectively (Shari and Soebarto, 2012).

3.4.3.1 Global Practices and Frameworks – Centralised Platform

Singapore's NEA offers a strong example of how centralised digital platform can support CE efforts. It connects stakeholders by offering access to directories of recycling facilities, material suppliers and CE experts, while also providing access to case studies, best practices and updated information on sustainable materials (Hoang et al., 2020). Adopting a similar platform in Malaysia could significantly strengthen the country's CE ecosystem by addressing current gaps in awareness, information access, stakeholder collaboration and accelerate innovation in waste recovery and sustainable construction practices.

3.4.3.2 Global Practices and Frameworks – Pilot Projects

The CIRCuIT initiative, funded by the EU Horizon 2020 programme, showcases how circular construction can be applied at the city level to support sustainability and reduce virgin material use by 20% in new developments, achieving cost savings of up to 15% (European Commission, 2023). It also developed digital tools to map CE initiatives, track material reuse, and engage the public, acting as a central hub for knowledge sharing (European Commission, 2023).

The Buildings as Material Banks (BAMB) initiative promotes the concept of buildings as material storage systems, designed for disassembly, adaptability, and material recovery (Leising, Quist, and Bocken, 2018). Other than introducing Material Passports, which are the digital records of building materials to enable future reuse and recycling (Chang, 2020), BAMB also tested these concepts through pilot projects that applied

reversible design, circular renovations, and flexible construction strategies in urban settings (Haither Ali and Anjali, 2024).

3.4.4 Challenge 4: Sustainability measures not required by Client

Highlighted by Masyhur et al. (2024), the lack of client demand is primarily due to limited awareness of the benefits of sustainable building and the perception that sustainability increases costs and reduces profitability. In Malaysia, most construction projects only meet the bare minimum sustainability requirements rather than adopting a holistic CE approach. This is evident in Malaysia's Green Building Index (GBI) certification data, where 65% of certified projects fall within the lowest rating category, indicating that most developers prioritize compliance over high-performance green buildings. Additionally, only 4% of projects have achieved Platinum certification (GBI, 2024), further reinforcing the notion that few clients actively demand the highest sustainability standards.

3.4.4.1 Global Practices and Frameworks – Amsterdam Circular Strategy

The Amsterdam Circular Strategy is the integration of circular criteria into tendering processes for both public and private sector projects. This ensures that CE practices, such as sustainable designs, material reuse, modular construction and end-of-life disassembly, are not merely recommended but required during the early stages of project planning and procurement, offering a valuable model for Malaysia to adopt (Haither Ali and Anjali, 2024).

3.4.4.2 Global Practices and Frameworks – Germany's quota for green materials in public procurements

Germany's green material quota in public procurement mandates the use of environmentally friendly materials in public construction projects, serving as a key policy to advance CE adoption (Wettengel, 2024). This approach boosts market demand for sustainable materials, encourages greener production among suppliers, and sets a precedent for the private sector making green material usage a requirement rather than an option.

IV. RESEARCH METHOD

This study adopts a quantitative research approach to explore CE practices within Malaysia's construction industry. A structured questionnaire was developed to assess CE awareness, policy effectiveness, implementation challenges, global best practices, and potential strategies for improvement. The questionnaire employed a 5-point Likert scale and was distributed to 50 - 100 industry professionals across various roles and sectors. A combination of purposive and snowball sampling was used to target respondents with relevant experience in CE or sustainability-related construction practices. Descriptive statistics such as frequencies, percentages, and mean scores were used to analyse and interpret the collected data.

In addition to quantitative data, open-ended responses within the questionnaire were analysed qualitatively using thematic analysis. An inductive coding approach was adopted to allow themes to emerge directly from the data, rather than being pre-imposed. Responses were first reviewed to identify recurring words, phrases, or ideas. These were then grouped into preliminary codes, which were refined into broader categories or themes reflecting key barriers, opportunities, and stakeholder insights regarding CE implementation. This analysis provided deeper context to the quantitative findings and helped uncover nuanced perspectives that may not be captured through closed-ended questions.

CONCLUSION

CE is increasingly recognised in Malaysia's construction industry, particularly among stakeholders involved in sustainable projects. However, voluntary adoption alone has proven insufficient due to the absence of mandatory policies and inconsistent implementation. This reinforces the need for a robust regulatory framework tailored to address industry-specific challenges. Establishing a dedicated CE blueprint focused on construction by learning from international models will provide the guidance and consistency needed for long-term industry transformation. As CE policies continue to develop, future research should assess their long-term effectiveness, integration, and real-world impact. In parallel, exploring the role of advanced technologies in supporting CE through predictive waste management and improve material flow visibility to ensure project efficiency. Cost-benefit analyses of CE strategies are also recommended to demonstrate financial viability and encourage broader adoption among developers and contractors.

ACKNOWLEDGMENT

The main author would like to express her gratitude to the School of Energy, Geoscience, Infrastructure, Society (EGIS) at Heriot-Watt University Malaysia, especially the supervisor for funding this publication. The main author would also like to express her sincere appreciation and gratitude to her supervisors for their invaluable guidance, continuous support, encouragement and understanding throughout the preparation of this dissertation.

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THE UNETHICAL PRACTICES IN CONSTRUCTION INDUSTRY: UNREVEALED CHALLENGES FROM PRACTITIONERS

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ABSTRACT

Construction industry is highly uncertain as it involves various parties. This caused problems related to unethical practices that overshadowed the accomplishments of this industry. The unethical practices have raised concerns because it tarnish the trustworthiness and viability among stakeholders. Therefore, this study focuses on the types and causes of unethical practices in the construction industry. The interviews shall be conducted with 15 practitioners to obtain their perceptions of the unethical practices. The findings from this study could enhance the understanding of unethical practices that plague the local construction industry. Thus, construction stakeholders can foster a culture of integrity and accountability towards the success of construction projects.

Keywords: Unethical practices, Ethical standard, Construction project

XI. INTRODUCTION

Construction plays a vital role in Malaysia's economic development (Dehdasht et al., 2021). However, despite its progress, the industry faces a significant threat due to unethical practices that undermine public trust, hinder fair competition, and slow socioeconomic advancement. These unethical actions can also compromise the safety and quality of construction projects (Rahman et al., 2007). Other than that, these malpractices often lead to cost overruns, project delays, and substandard workmanship, ultimately affecting stakeholders at all levels. The problem of unethical practices in the Malaysian construction industry is complex and stems from a range of institutional, cultural, and economic issues (Mail, 2024). The construction industry is particularly prone to unethical conduct, making up a substantial portion of these unethical practices. Especially during situations when several stakeholders are involved, collaboration among varied specialists is crucial. This is because professional ethics differ among individuals and within the construction industry (Shah & Alotaibi, 2018). Without strict enforcement of ethical guidelines and regulatory frameworks, these challenges may continue to hinder the industry's long-term growth and sustainability (Ali et al., 2020).

The consequences of unethical practices are severe, often leading to project abandonment, cost overruns, and poor construction quality. Due to conflicting interests, professionals in the industry often engage in unethical competition, negatively affecting projects (Aigbavboa et al., 2016; Paul, 2020). This has led to project abandonment, cost overruns, and poor quality. Ethics play a crucial role for individuals and the industry, as ethical behavior significantly influences project outcomes. Therefore, implementing strict ethical guidelines, transparency measures, and accountability frameworks is essential to mitigating these issues and ensuring sustainable project success (Ameyaw et al., 2017). Besides, strengthening ethical standards is crucial for improving the integrity and sustainability of Malaysia's construction industry, especially amid rising corruption cases (Star Media Group Berhad, 2023).

Unethical practices in the construction industry encompass various actions that deviate from ethical standards and principles. These practices can undermine project quality, harm stakeholders, and erode public trust in the industry. Due to its high capital expenditures, the construction industry is particularly vulnerable to unethical practices, creating opportunities for rent-seeking practices (Shah & Alotaibi, 2018). Every phase of a construction project, from conceptualization to execution, is susceptible to unethical conduct due to the involvement of time, money, resources, and technology (Ehsan et al., 2009). Such unethical actions can lead to unnecessary or unsuitable projects that are costly, complex, and prone to significant delays (Adnan et al., 2012).

Prior studies by Rahman et al. (2010) & Maseko (2018) revealed that 74% of construction industry participants engaged in several unethical practices over the past decades. According to Vee & Skitmore (2003), unethical practices in the construction industry typically manifest as corruption, bribery, cronyism, nepotism, and favoritism. Moreover, some of the unethical practices highlighted in the construction industry include conflict of interest, bribery, claim games, kickbacks, collusive tendering, change order games, and fraud (Akinrata, 2019). Besides, concerns about short and late payments as well as the unfair treatment of contractors during talks were identified as a part of unethical practices. As a result, the focus on unethical practices in the construction industry has not been fully addressed as unethical practices can often take different forms, and the scope of the investigations has not been very specific (Ho, 2013).

The continuance of unethical practices during project construction indicates an unsolved issue. Factors contributing to these practices include personal gain, work culture, enforcement gaps, and political and economic influences (Auoad, 2018). Examples include professionals exaggerating their skills for higher compensation or disclosing trade secrets for personal benefits (Ferrell & Weaver, 1979; Olatunji et al., 2016; Ibrahim et al., 2021). Weak ethical standards, inadequate supervision, and close ties between contractors further increase the likelihood of unethical behavior (Le et al., 2014). These unethical behaviors not only compromise project quality and efficiency but also hinder industry growth and public trust (Hanapi et al., 2023).

Unethical practices in the construction industry have severe and far-reaching consequences, affecting multiple aspects of the sector and its stakeholders. These include compromised safety, financial losses, reputational damage, and legal issues, emphasizing the urgent need for ethical reform (Azhar et al., 2008; Shah & Alotaibi, 2018). Such practices contribute to project delays, poor quality, and environmental harm, ultimately hindering economic and workforce development (Rahman et al., 2010). Corruption also discourages foreign investment and increases financial strain on clients and governments, lowering overall quality of life (Melgar et al., 2010; Shah & Alotaibi, 2018). If left unaddressed, these unethical behaviors will continue to erode trust in the industry, making it difficult to implement sustainable and efficient construction practices.

Studies on unethical practices have been conducted in various countries, including Pakistan, Nigeria, and China (Paul, 2020). However, research in Malaysia has mainly classified unethical behaviors rather than explored their root causes (Shah & Alotaibi, 2017; Hamid et al., 2019; Ibrahim et al., 2019; Rahim et al., 2021). Therefore, this study is conducted to explore unethical practices among all stakeholders involved in construction projects. The research objectives are 1) To identify the types of unethical practices in the local construction industry, 2) To determine the causes of unethical practices in the local construction industry. The content of this paper consists of a literature review, research scope, research methodology and expected outcome.

XII. LITERATURE REVIEW

Unethical practices in the construction industry involve actions that deviate from ethical standards, integrity, and fairness, ultimately affecting industry performance and productivity (Rahman et al., 2014). These practices undermine credibility, trust, and professional relationships, often stemming from greed, breaches of conduct, and morally unacceptable behaviors (Aigbavboa et al., 2016). They not only harm individuals and organizations but also negatively impact stakeholders, project outcomes, and the economy (Rahim et al., 2021). Common unethical practices include bid rigging, bribery, tender manipulation, and corruption aimed at gaining undue advantages (Amoah & Steyn, 2022). These issues are widespread globally, affecting professionals, organizations, and economies. In conclusion, unethical practices create obstacles to integrity, trust, and long-term success in the construction industry. Addressing these issues is essential for maintaining ethical standards, fair competition, and sustainable growth.

A. Types of Unethical Practices

The construction industry is often affected by unethical practices that compromise project integrity, efficiency, and safety. Recent studies have identified several prevalent unethical practices in the sector. According to Hanapi et al. (2023), corruption and bribery are among the most significant ethical challenges, where stakeholders engage in illegal payments or favoritism to secure contracts. This practice distorts fair competition and leads to inflated project costs. Similarly, Kuoribo et al. (2021) highlighted collusion and unfair conduct, where contractors manipulate the tendering process through prearranged agreements, ultimately undermining transparency and increasing project expenses. These unethical practices not only hinder industry growth but also erode public trust in construction professionals and regulatory bodies.

Another major issue is fraudulent billing and overpricing, as discussed by Ibrahim et al. (2021). This includes practices such as overbilling, falsifying claims, and misrepresenting costs, leading to financial losses and disputes. Additionally, embezzlement involving misappropriating funds meant for project execution leads to financial losses and project delays (Yap et al., 2022). These unethical financial practices not only burden clients and investors but also weaken industry credibility and trust among stakeholders. If left unchecked, such malpractices can discourage future investments and hinder the sustainable growth of the construction sector.

Other prevalent unethical practices include tender withdrawal, where bidders retract their submissions, disrupting procurement processes (Ameh & Odusami, 2021), and conflicts of interest, where decision-makers prioritize personal or corporate gains over project integrity (Rahman et al., 2020). Additionally, violations of environmental ethics, such as disregarding sustainability regulations, can cause long-term ecological harm (Zainal et al., 2022). These unethical practices not only compromise project efficiency but also lead to legal disputes and damage the reputation of involved firms.

In conclusion, unethical practices in the construction industry severely impact project integrity, efficiency, and sustainability. Corruption, collusion, fraudulent billing, and conflicts of interest continue to undermine transparency, inflate costs, and erode public trust. Financial misconduct, such as embezzlement and overpricing, further weakens industry credibility and discourages future investments. Additionally, environmental violations contribute to long-term ecological harm, affecting sustainable development. Addressing these issues through stricter regulations, ethical awareness, and industry-wide reforms is crucial for fostering a more transparent and sustainable construction sector.

B. Causes of Unethical Practices

Unethical practices in the construction industry arise from various sources, often linked to systemic weaknesses, financial pressures, and a lack of enforcement. One significant cause is weak regulatory enforcement, where the absence of strict monitoring and penalties allows unethical practices to persist (Youssef et al., 2023). Many construction firms exploit regulatory loopholes to engage in corrupt activities, such as bid rigging and overbilling, without facing serious consequences. Additionally, the lack of transparency in procurement processes further encourages unethical dealings, as stakeholders manipulate contracts for personal or corporate gains (Ibrahim et al., 2022).

Another major cause is financial pressure and profit-driven motives, which push companies to cut corners and manipulate contracts to maximize financial gains (Rahim et al., 2021). Due to intense competition, contractors and consultants may engage in bribery or fraud to secure projects, leading to unethical decision-making. This practice not only distorts fair market competition but also compromises project quality and safety standards (Ibrahim et al., 2022). Furthermore, the lack of ethical standards in the construction industry creates uncertainty regarding ethical expectations, allowing industry members to exploit loopholes for personal gain (Utilitiesone, 2023; Hyatt & Gruenglas, 2023). This lack of clear guidelines leads to unethical practices such as prioritizing profit over quality, ultimately compromising project integrity, diminishing stakeholder trust, and tarnishing the industry's reputation (Netscher, 2017).

Additionally, project complexity increases the likelihood of unethical practices due to a lack of transparency, making it difficult for stakeholders to detect irregularities in financial transactions and contract terms (Stifi, 2017; Shan et al., 2020). The intricate nature of these projects adds pressure on stakeholders, incentivizing unethical behavior to navigate challenges (Lafhaj et al., 2024). Project uncertainties, including unpredictable site conditions and market fluctuations, also further contribute to unethical practices as firms seek short-term survival strategies (Ibrahim et al., 2019; Judson & Paul, 2019). Similarly, economic downturns reduce demand for construction projects, causing cash flow difficulties that drive some firms to commit fraud, delay payments, or refuse to pay suppliers (Low & Lau, 2019; Akinsiku & Ajayi, 2016). Some developers may also engage in bankruptcy fraud to avoid financial losses during economic hardships (Kate, 2023).

Negative role models in the construction industry contribute to unethical practices by normalizing misconduct such as bid rigging, bribery, and fraud (Brown & Mitchell, 2010; Mitchell et al., 2023). The lack of accountability in such cases fosters a culture where unethical practices are tolerated, ultimately eroding trust and integrity within the industry. Political influence also plays a role, as political interventions in tender awards and regulatory decisions can lead to favoritism, bid-rigging, and reduced transparency (Chang et al., 2018; Sims, 2024). When government officials pressure the awarding of contracts to preferred contractors, fair competition is compromised, inflating costs and reducing accountability (Klinken & Aspinall, 2011; Rahman, 2012). Additionally, conflicts of interest arise when stakeholders prioritize personal or financial relationships over professional obligations, leading to biased procurement decisions, inflated costs, and diminished project quality (Hamid et al., 2019; Ethics Unwrapped, 2022).

Unethical practices in the construction industry arise from weak regulatory enforcement, financial pressures, and a lack of ethical standards, allowing corruption such as bid rigging and overbilling to persist. Project complexity and uncertainties further enable unethical practices by making irregularities difficult to detect, while economic downturns push firms toward fraudulent activities to mitigate financial losses. Negative role models and political influence normalize unethical practices, eroding trust and integrity within the industry. Conflicts of interest also contribute to biased procurement decisions, inflated costs, and compromised project quality. Strengthening regulations, promoting transparency, and enforcing ethical standards are essential to restoring integrity in the construction sector.

XIII. RESEARCH SCOPE

The study area for this research is within the Klang Valley which includes Selangor and Wilayah Persekutuan. According to Aiman (2021), Kuala Lumpur and Selangor are the most exposed to unethical practices. Followed by the news published by Star Newspaper (2023) claimed that these two states are more exposed to unethical practices such as bribery, money laundering, and corruption compared to other states.

Apart from that, Selangor and Wilayah Persekutuan are among the major contributors to the value of construction work done in local construction. In addition, there are a wide variety of construction projects, from modest residential developments to huge infrastructure undertakings (Department of Statistics Malaysia Official Portal, 2022). Likewise, the targeted respondents will cover the practitioners that work with the architect firms, quantity surveyor firms, engineering firms, contractor firms as well as work with developer firms. This diversity makes it possible to generalize the findings based on all stakeholders involved in construction projects.

XIV. RESEARCH METHODOLOGY

The research follows a structured methodology divided into three main stages: Initial Stage, Intermediate Stage, and Final Stage as illustrated in Figure 1.

A. Initial Stage

The research begins with identifying the research area, followed by a review of the background and problem statement. Once the issue is established, the research aims and objectives are determined. The next step involves defining the scope of research, population, and sample to ensure clarity in data collection. A literature review is conducted to gather insights into the types and causes of unethical practices in the construction industry. Based on this, the research methodology is established, employing a qualitative method using semi-structured interviews. The final step in this stage is designing the interview questions for the pilot study.

B. Intermediate Stage

A pilot study will be conducted by interviewing five construction practitioners to refine the research approach and improve the interview questions. After analyzing the pilot study findings, individual interviews will be carried out with a purposive sample of 15 practitioners from architect firms, quantity surveyor firms, engineering firms, contractor firms, and developer firms. The collected data will be analyzed using ATLAS.ti software for qualitative content and thematic analysis. This approach ensures a comprehensive understanding of industry perspectives on unethical practices. The findings will help identify key themes, trends, and statistical insights, providing valuable recommendations for improving ethical standards in the construction industry.

C. Final Stage

The research will conclude with a comprehensive analysis of the findings, summarizing the key insights on unethical practices in the construction industry before finalizing the study. This structured methodology will ensure a systematic and reliable investigation into the issue while incorporating diverse perspectives from industry professionals. The study will highlight the types and root causes of unethical practices, providing a well-rounded understanding of the challenges faced by the industry. By identifying critical areas for improvement, the research will offer practical recommendations to enhance ethical standards and regulatory enforcement. Ultimately, the findings will aim to contribute to a more transparent, accountable, and sustainable construction sector.

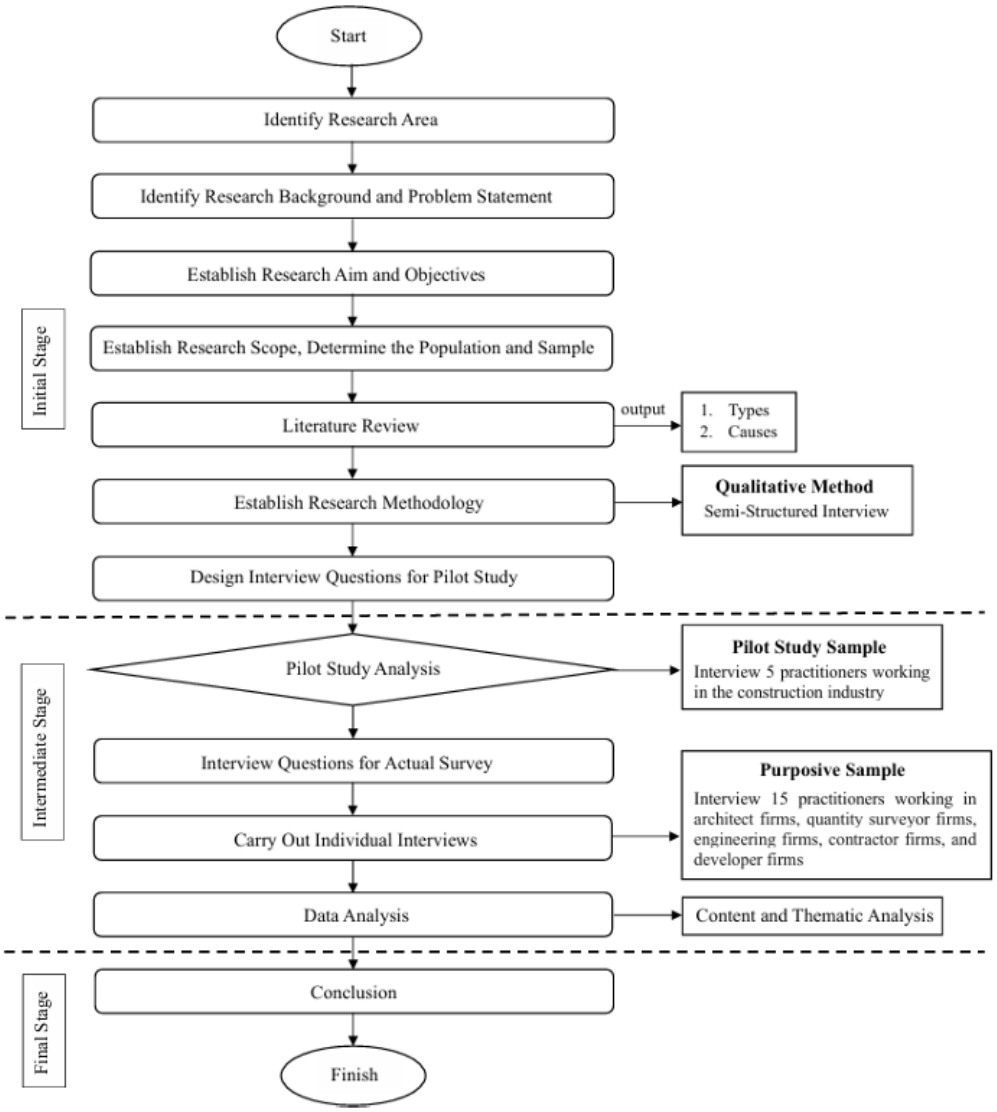


Figure 1.0 Research Design

XV. EXPECTED OUTCOME

This research seeks to provide a comprehensive understanding of unethical practices in the local construction industry by identifying common types and underlying causes. It will highlight issues such as bribery, fraud, collusion, and bid-rigging, exploring the factors contributing to these malpractices, including weak enforcement, lack of transparency, and financial pressures. The findings will serve as a foundation for improving industry ethics and fostering a culture of integrity, ultimately promoting sustainable growth and professionalism in the construction sector. Moreover, by enhancing the understanding of this issue, perhaps this study might aspire to enhance accountability and ethical compliance among the practitioners.

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STRATEGIES TO MITIGATE THE IMPACTS OF SINKHOLE ON PROPERTY PRICES IN MALAYSIA

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ABSTRACT

Sinkholes have emerged as a significant concern in Kuala Lumpur due to its region's geological makeup and rapid urban development. Properties located in sinkhole-prone areas are at considerable risk, both from direct physical damage and from the perceived threat of future sinkhole formation, which undermines market confidence. Despite international research addressing sinkhole impacts on real estate industry, Malaysia lacks localized strategies to mitigate these risks, particularly in the Kuala Lumpur area. This research seeks to fill this gap by developing strategies tailored to the Malaysian context. The main objectives of this research are to examine the impacts of sinkhole risks on property prices and to investigate effective strategies for mitigating these impacts in sinkhole-prone areas. This research, based on a comprehensive literature review, provides a conceptual framework for addressing sinkhole-related challenges in the Malaysian real estate market. Given the constraints of primary data, the findings and proposed strategies are theoretical and drawn from existing research. The expected findings aim to provide significant insights into mitigating the economic impacts of sinkholes on property prices. The proposed strategies are expected to contribute to the development of localized policies, enhancing the resilience of Kuala Lumpur's real estate market and offering practical recommendations for developers, investors, and policymakers.

Keywords: sinkholes, karst topography, property prices, property valuation, mitigation strategies

XVI. INTRODUCTION

Sinkholes, a geological hazard caused by the collapse of the ground surface into voids created by the dissolution of soluble rocks like limestone, dolomite, or gypsum, are increasingly becoming a concern, particularly in areas with karst topography. These hazards are often exacerbated by human activities such as excessive groundwater extraction, deforestation, and urbanization. Globally, sinkholes have become a significant geohazard in karst regions, such as Florida, the Netherlands, and parts of China. In Florida, sinkhole-prone areas have seen property prices drop by up to 30% due to the perceived risks of ground instability (Dumm, Smersh, & Sirmans, 2020). Similarly, in the Netherlands, property prices have decreased by up to 6% in regions affected by sinkholes, with uncertainty about future ground instability deterring buyers (Willemsen, Kok, & Kuik, 2020). In China, rapid urban expansion and groundwater over-extraction have heightened sinkhole risks, leading to significant declines in property prices (Wu, Zhang, & Shen, 2021). In Malaysia, such as in cities like Kuala Lumpur, rapid urban sprawl and groundwater over-extraction have heightened the risks of sinkhole formation, leading to significant economic consequences, particularly in real estate markets. The 2024 sinkhole incident at Jalan Masjid India serves as a critical case study. This event, which tragically resulted in the death of an Indian tourist, underscored the geological vulnerabilities of the city, where the limestone composition of the soil, combined with underground water flow, led to the collapse. The Deputy Prime Minister of Malaysia confirmed that the incident was caused by geographical and soil structure factors, making the area particularly susceptible to future sinkhole events (Bernama, 2024). Properties in sinkhole-prone zones experience depreciation due to the perceived risks of collapse, discouraging investment and lowering property prices. While international research has documented the impacts of sinkholes on property prices, there is a research gap concerning Malaysia, especially in high-risk urban areas. According to the sinkhole susceptibility hazard zone map by Rosdi et al. (2019), certain areas in Kuala Lumpur are at significantly higher risk of sinkhole formation. Figure 1.0 further highlights the need for focused research on the impacts of sinkhole on property prices and relative strategies to mitigate these impacts in Malaysia.

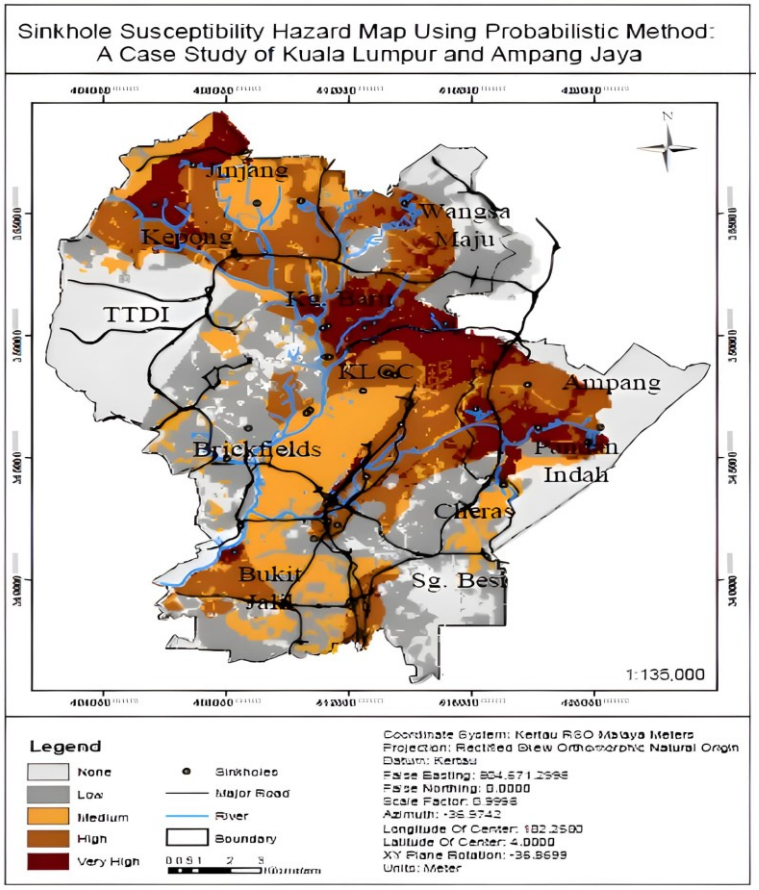


Figure 1.0 *Sinkhole Susceptibility Hazard Zone Map (Rosdi et al.,2019)*

The main objectives of this paper are to examine the impacts of sinkhole formation on property prices in affected regions and investigate strategies to mitigate these impacts, focusing on solutions that can safeguard property prices and guide sustainable urban development.

XVII. SINKHOLES

Sinkholes are depressions or cavities formed when underlying material collapses, typically in areas with soluble bedrock such as limestone, dolomite, or gypsum. This dissolution process occurs when water interacts with the bedrock, creating underground voids that eventually lead to surface collapse or subsidence. There are three primary types of sinkholes: *solution sinkholes, subsidence sinkholes*, and *collapse sinkholes*.

Solution Sinkholes form when rainwater, slightly acidic due to absorbed carbon dioxide, directly interact with exposed bedrock or a thin layer of soil or sediment, gradually dissolving the rock and creating surface depressions. These sinkholes develop over time, and while they may not cause immediate, dramatic damage, they can affect property values by restricting land use in the affected areas (Banks et al., 2020). Figure 2.0 shows the formation of *Solution Sinkholes*.

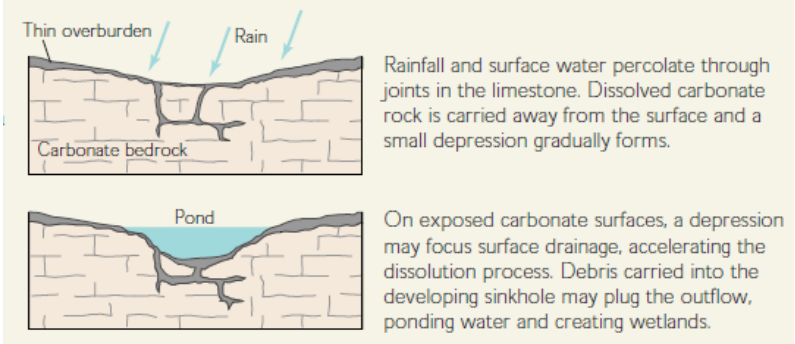


Figure 2.0 *Solution Sinkholes* (Tihansky, 1999)

Subsidence Sinkholes occur when loose sediment overlay bedrock. Over time, the sediment filters into voids created by rock dissolution, causing the surface to gradually lower. Although these sinkholes may not result in

sudden, large-scale damage, they can lead to the progressive devaluation of property prices due to the perceived instability of the land (Nam et al., 2020). Figure 3.0 shows the formation of *Subsidence Sinkholes*.

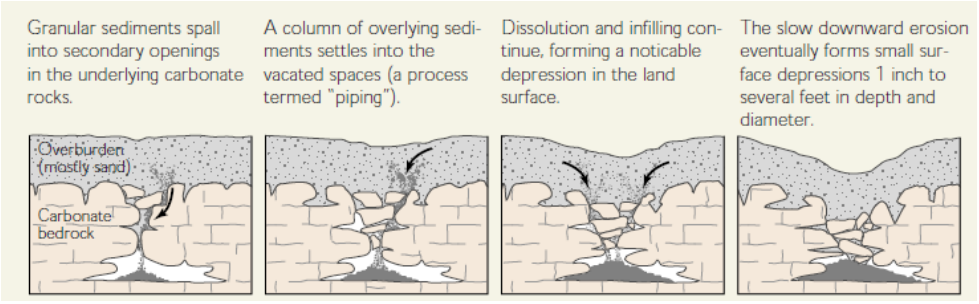


Figure 3.0 *Subsidence Sinkholes* (Tihansky, 1999)

Lastly, *Collapse Sinkholes* are the most sudden and hazardous type, occurring when the roof of a subsurface cavity becomes unable to support the weight of the overlying material. This causes a rapid and often dramatic surface collapse. Collapse sinkholes can render land unsuitable for residential or commercial use, leading to sharp declines in property value due to the immediate loss of stability and functionality (Ramírez-Serrato et al., 2024). Figure 4.0 shows the formation of *Collapse Sinkholes.*

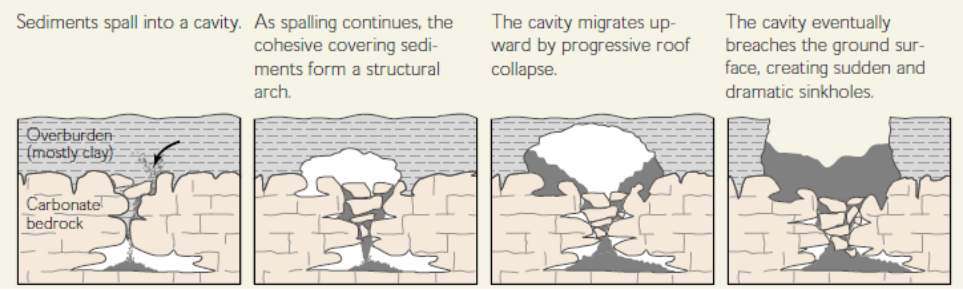


Figure 4.0 *Collapse Sinkholes* (Tihansky, 1999)

XVIII. IMPACTS OF SINKHOLES ON PROPERTY PRICES

Sinkholes are significant geohazards that not only cause physical damage but also profoundly affect property values, both immediately and in the long term. Immediate price depreciation occurs due to structural damage, while long-term devaluation is influenced by perceived risks and market behavior, which impact property demand. Understanding these economic consequences is vital for stakeholders, such as real estate investors, property developers, and homeowners, in sinkhole-prone regions.

A. Direct Economic Impact: Immediate Devaluation of Property Prices

The immediate economic impact of a sinkhole is the physical damage it causes to properties, leading to a direct decrease in property value. Sinkholes typically cause structural damage to buildings, roads, and other infrastructure, ranging from minor cracks to the collapse of entire buildings. This damage often necessitates costly repairs and can make properties unsafe or uninhabitable, further driving down market prices.

For instance, Tihansky (2020) found that properties in West-Central Florida directly impacted by sinkholes experienced a 30% reduction in market value. The immediate price reduction stems from several factors: repair costs, the perceived danger associated with sinkhole damage, and market stagnation. The cost of repairs, even if the property is fixable, often reduces the buyer's willingness to pay. Moreover, the stigma attached to properties with sinkhole damage—due to concerns about future incidents—discourages potential buyers. In some cases, properties may remain on the market for extended periods without recovering their pre-sinkhole value, even after repairs are made.

B. Indirect Economic Impact: Perceived Risk and Market Behavior

Beyond the physical damage, sinkholes also have an indirect economic impact on property prices, largely driven by the perceived risk of living in sinkhole-prone areas. Even properties that have not been directly affected by sinkholes can suffer a decrease in value due to the psychological effects on potential buyers. Proximity to sinkhole-prone zones often results in devaluation due to the fear of future sinkhole formation.

Studies show that location-based risks, such as proximity to sinkhole-prone areas, are crucial in determining property value. This is primarily due to psychological aversion and risk perception. Buyers may avoid areas with a perceived risk of sinkholes, even if the properties themselves have never experienced

sinkhole damage. Mohammad et al. (2020) observed that in Kuala Lumpur, properties near karst landscapes, which are susceptible to sinkhole formation, often experienced lower demand due to the fear and uncertainty surrounding the safety of the land. In Florida, Tihansky (2020) found that the perceived risk of sinkholes had a more significant effect on property prices than actual sinkhole damage. Properties in areas near sinkhole-prone zones were often devalued, not because of past damage, but due to the psychological effect of potential future sinkholes.

C. Long-Term Economic Impact: Market Stagnation and Reduced Demand

The long-term economic consequences of sinkholes on property values go beyond immediate devaluation and perceived risk. Areas prone to sinkholes may face market stagnation, where properties remain unsold for extended periods due to the uncertainty surrounding future risks. As demand for properties decreases, the supply-demand balance shifts, leading to prolonged unsold properties and reduced market liquidity.

Tihansky (2020) found that in Florida, properties in sinkhole-prone areas often experienced long-term market stagnation. The fear of future sinkhole formation led to low demand, causing properties to remain unsold for months or even years. This stagnation reduced overall market activity and caused long-term price depreciation. Similarly, Mohammad et al. (2020) observed that in Kuala Lumpur, areas near sinkhole-prone zones faced reduced investment from developers and buyers, leading to long-term price stagnation. As these properties became increasingly avoided, the overall market growth in these regions slowed, contributing to lower property values over time.

XIX. STRATEGIES TO MITIGATE IMPACTS OF SINKHOLES ON PROPERTY PRICES

This section explores strategies to mitigate the impacts of sinkholes on property prices, drawing from both international and local studies on sinkhole risks. The strategies are categorized into geotechnical, urban planning, technological, public engagement, and policy-based approaches, offering a comprehensive framework for application in sinkhole-prone areas such as Kampung Baru, Kuala Lumpur.

A. Geotechnical Solutions

Geotechnical methods are vital in stabilizing ground conditions and preventing further sinkhole subsidence. Techniques such as compaction grouting, which involves injecting a cement-like material to fill voids, and soil reinforcement with geosynthetics, have proven effective in stabilizing karst regions (Gracia et al., 2023). In Alcalá de Ebro, Spain, Gracia et al. (2023) demonstrated how compaction grouting combined with geogrid reinforcement successfully stabilized the ground, preventing further damage to infrastructure and properties. Additionally, polyurethane injections have been found to effectively fill voids and reinforce soils in karst terrains, providing significant protection against sinkhole formation (Esposito et al., 2021).

B. Urban Planning and Zoning Policies

Urban planning and zoning regulations are essential for mitigating sinkhole risks. Incorporating sinkhole hazard assessments into development plans can prevent exposure to high-risk zones, thereby reducing potential property devaluation. For example, in Perdiguera, Spain, zoning maps guided development away from high-susceptibility areas, helping mitigate risks of property price loss (Torrijo et al., 2020). Implementing similar zoning frameworks in Malaysia, especially in areas like Kampung Baru, could effectively manage urban growth in sinkhole-prone zones, reducing the risk of long-term devaluation.

C. Technological Innovations

Technological advancements have significantly improved the prediction and prevention of sinkholes. Tools like satellite-based A-DInSAR, ground-penetrating radar (GPR), and electrical resistivity imaging (ERI) enable the early detection of subsurface anomalies that may lead to sinkholes (Gutiérrez et al., 2014; Esposito et al., 2021). For instance, in Rome, the integration of A-DInSAR and geological modelling successfully identified high-risk zones, allowing for preventive actions to be taken before property values were severely impacted (Esposito et al., 2021). Similar technologies could be beneficial in high-density urban areas like Kuala Lumpur, facilitating early intervention and minimizing economic losses.

D. Stakeholders Engagement and Public Awareness

Engaging stakeholders and raising public awareness is critical in mitigating the economic impacts of sinkholes on property prices. Educating property owners, developers, and potential buyers about sinkhole risks and available mitigation measures can improve market confidence and reduce the stigma associated with high-risk areas (Dumm, Smersh, & Sirmans, 2020). In karst-prone regions, collaborative efforts between local authorities and real estate professionals have helped inform buyers, ensuring that decisions are made based on facts rather

than fear, thereby stabilizing property values.

E. Financial and Policy Interventions

Financial mechanisms and policy interventions play a key role in reducing the financial burden of sinkhole risks. Mandatory sinkhole insurance and government subsidies for mitigation projects can protect property owners and stabilize property values. In Florida, mandatory sinkhole insurance has provided homeowners with financial security, helping to maintain property values in affected areas (Gracia et al., 2024). Furthermore, government-funded stabilization programs, such as soil grouting and land reclamation projects, have been implemented to restore buyer confidence and encourage investments in sinkhole-prone zones.

F. Integration of Multiple Strategies

The most effective approach to mitigating sinkhole risks involves the integration of multiple strategies. In Gallur, Spain, authorities successfully combined geotechnical solutions, zoning policies, and public awareness campaigns to stabilize infrastructure and restore market confidence (Gracia et al., 2024). For high-risk areas like Kampung Baru, adopting a multifaceted approach could help mitigate property devaluation and promote sustainable urban development.

CONCLUSION

Sinkholes present a significant challenge to property markets, particularly in areas with karst topography like Kuala Lumpur. The economic impacts of sinkholes on property prices are both immediate and long-term, affecting not only the physical value of properties but also market perception and investment behaviours. While the direct damage from sinkholes results in immediate devaluation, the perceived risk of sinkhole formation in surrounding areas can lead to broader market stagnation. However, through a combination of geotechnical solutions, urban planning, technological innovations, and public awareness, these impacts can be mitigated. By integrating these strategies, local authorities and developers can reduce risks and foster more sustainable urban growth, ensuring that property markets in sinkhole-prone regions remain resilient. Overall, this paper provides a conceptual framework for mitigating the impact of sinkholes on property prices in Malaysia, offering strategies derived from global literature. These strategies, though primarily conceptual and drawn from existing literature, provide a theoretical framework for local authorities and developers to reduce risks and promote more sustainable urban growth. Future research would benefit from the collection of primary data, such as case studies or empirical analyses, to validate these strategies, evaluate their practical feasibility and further refine these recommendations to ensure higher effectiveness.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to the Faculty of Built Environment and Surveying of Universiti Teknologi Malaysia (UTM), as well as my supervisor, Dr Norhidayah Binti Md. Yunus, for their generous funding and support in making this publication possible. I am deeply grateful for their guidance and encouragement throughout this work.

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THE IMPACT OF RISING PROPERTY VALUES IN HULU LANGAT, SELANGOR ON MIDDLE- AND LOWER-INCOME CITIZENS

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ABSTRACT

Aligned with Sub-theme 3 on built environment sustainability and conservation, this research delves into the escalating property values in Hulu Langat, Selangor, and Kuala Lumpur over the past decade regarding a phenomenon that has introduced profound socio-economic challenges, particularly for middle- and low-income groups. This study critically examines the interplay of key contributing factors, including urban expansion, surging residential demand, and escalating land costs, which, while indicative of economic growth and urbanization, have simultaneously exacerbated barriers to housing affordability. The widening disparity between property prices and income levels has intensified housing insecurity, further entrenching socioeconomic inequalities within these regions. A critical concern is the mounting difficulty faced by lower-income households in securing housing within reasonable proximity to employment hubs, educational institutions, and essential services which is an issue that directly impairs social mobility and threatens the cohesion of urban communities. Through a rigorous analysis of empirical data and a comprehensive review of existing literature, this study interrogates the structural and market forces propelling property appreciation in Hulu Langat and its surrounding areas. It also evaluates the disproportionate burden on vulnerable populations and assesses the efficacy of current housing policies and interventions. By dissecting the underlying mechanisms of housing unaffordability and its broader societal ramifications, this research contributes to the discourse on sustainable and inclusive urban development. The findings aim to inform policy frameworks that advance housing equity, ensuring that affordability remains a cornerstone of urban planning in Selangor and Kuala Lumpur, ultimately fostering more socially cohesive and economically accessible communities.

Keywords: Affordability, Housing, Inequality and Urbanization.

I. INTRODUCTION

The rapid urbanization and economic expansion of Malaysia over the past few decades have significantly influenced the socio-economic landscapes of its regions, particularly in areas adjacent to major metropolitan centers. This study focuses on the escalating property values in Hulu Langat, Selangor, and Kuala Lumpur over the past decade, a phenomenon that has introduced profound socio-economic challenges, especially for middle- and low-income groups. By critically examining the interplay of key contributing factors including urban expansion, surging residential demand, and escalating land costs this research aims to contribute to the discourse on sustainable and inclusive urban development.

A brief history and background of Hulu Langat to further understand the context and the situation of the area. Hulu Langat, located in the southeastern corridor of Selangor, has undergone significant transformations over the past century. Historically, between the conclusion of the Selangor Civil War in 1874 and the early 20th century, Hulu Langat evolved from a sparsely populated area into a region characterized by organized village patterns. Unlike the upper Klang and Selangor River valleys, which were rich in tin deposits and thus attracted substantial mining activities, Hulu Langat's development was more gradual due to the absence of such mineral wealth.

In contrast, Kuala Lumpur's origins are deeply rooted in the tin mining boom of the mid-19th century. Established in 1857 at the confluence of the Klang and Gombak rivers, the city rapidly transformed into a bustling commercial hub. The influx of Chinese miners and British colonial interests propelled its early growth, laying the foundation for its emergence as Malaysia's capital and largest city. The post-1950s era marked a significant phase of urbanization for Kuala Lumpur, driven by political decisions, globalization, and industrialization. This period witnessed the city's expansion beyond its original boundaries, incorporating surrounding areas and leading to the development of a contiguous urban landscape.

The rapid urbanization of Kuala Lumpur during the 1970s and 1980s had profound effects on its housing development and urban form (Shuid, 2016). As the city's population grew and economic activities intensified, the demand for residential and commercial spaces surged. This demand catalyzed the expansion of urban boundaries into adjacent districts, notably Hulu Langat (Abdullah et al., 2017). The district, once characterized by its rural landscapes and traditional villages, began to experience significant urban sprawl emanating from the metropolitan core (Rahman & Omar, 2020). This sprawl was marked by the proliferation of residential developments, commercial establishments, and infrastructural projects aimed at accommodating the overflow from Kuala Lumpur.

Furthermore, the encroachment of urban development into Hulu Langat brought about a surge in property prices, reflecting the heightened demand and the district's increasing integration into the greater Kuala Lumpur conurbation. While indicative of economic growth and urbanization, this escalation in property values has exacerbated barriers to housing affordability, particularly for lower-income households (Samad et al., 2016). The widening disparity between property prices and income levels has intensified housing insecurity, further entrenching socio-economic inequalities within these regions (Economic Planning Unit, 2015).

Besides that, the phenomenon of rising property prices in Hulu Langat and Kuala Lumpur has placed considerable pressure on middle- and low-income groups. The mounting difficulty faced by these households in securing housing within reasonable proximity to employment hubs, educational institutions, and essential services directly impairs social mobility and threatens the cohesion of urban communities. The Malay community in the suburbs of Hulu Langat, for instance, has been under pressure from urban sprawl as a result of the development of Kuala Lumpur Metropolitan that has exceeded its borders.

The challenges of housing affordability are further compounded by the broader national context. Between 2001 and 2019, the total value of the residential sector in Malaysia more than tripled, growing from approximately RM22 billion to RM72 billion, underscoring the impressive efforts to accommodate a growing urban population (Bank Negara Malaysia, 2020). However, this rapid appreciation in property values has outpaced income growth, rendering homeownership increasingly unattainable for many (Khazanah Research Institute, 2019). In Kuala Lumpur, for instance, median house prices were 5.4 times the median annual household income in 2014, surpassing the national average of 4.4 times (Demographia, 2015).

This study seeks to critically examine the structural and market forces propelling property appreciation in Hulu Langat and its surrounding areas. It aims to evaluate the disproportionate burden on vulnerable populations and assess the efficacy of current housing policies and interventions. By dissecting the underlying mechanisms of housing unaffordability and its broader societal ramifications, this research contributes to the discourse on sustainable and inclusive urban development. The findings aspire to inform policy frameworks that advance housing equity, ensuring that affordability remains a cornerstone of urban planning in Selangor and Kuala Lumpur. Ultimately, the goal is to foster more socially cohesive and economically accessible communities, where the benefits of urban growth are equitably shared among all residents.

II. LITERATURE REVIEW

The housing affordability crisis in Kuala Lumpur and Selangor has become a pressing concern, as rising property prices continue to outpace income growth, creating significant challenges for middle- and low-income households. This issue is particularly evident in rapidly urbanizing districts like Hulu Langat, where the spillover effects of Kuala Lumpur's metropolitan expansion have driven up land and housing costs. The widening gap between household income levels and escalating property values has resulted in reduced accessibility to homeownership, forcing many residents to either compromise on housing quality or relocate to more distant, less-developed areas. This situation has broader socioeconomic implications, as housing is not only a fundamental human necessity but also a crucial factor in determining financial stability, social mobility, and overall well-being (Samad et al., 2016).

One of the primary consequences of limited affordable housing options is the relocation of lower-income groups to peripheral regions, where housing remains relatively cheaper but often lacks essential infrastructure and public services. As residents move farther from city centers, they face increased commuting times and transportation expenses, which further strain household budgets and reduce overall quality of life. Long commutes not only consume significant time and financial resources but also contribute to increased carbon emissions and environmental degradation, challenging the principles of sustainable urban development (Samad et al., 2016). Additionally, families forced into substandard housing conditions in urban areas often face issues such as overcrowding, poor ventilation, inadequate sanitation, and lack of access to green spaces—factors that negatively impact health and social well-being.

Beyond the direct financial burden of homeownership, high housing costs limit disposable income for other essential needs, including healthcare, education, and savings, thereby perpetuating financial instability. Households that allocate a disproportionate share of their income toward rent or mortgage payments may struggle to invest in children's education, afford quality healthcare, or build financial security for the future. This economic strain also affects local economies, as lower disposable income reduces consumer spending, potentially slowing economic growth in affected communities. Affordable housing policies are therefore

crucial not only for ensuring adequate shelter but also for promoting long-term economic resilience and social equity (Samad et al., 2016).

In Hulu Langat, the impact of housing unaffordability is particularly severe among rural citizens who face mounting difficulties in acquiring their own homes. As property investors and developers target strategic locations near Kuala Lumpur, local populations are often outpriced from the market. This trend has led to the displacement of long-established communities, where families who have lived in the region for generations are forced to migrate due to financial pressures. In many cases, houses originally owned by locals are being purchased by external investors, leading to gentrification and cultural erosion. This dynamic further deepens social inequality, as wealthier investors benefit from property appreciation while lower-income groups face declining housing security and reduced opportunities for homeownership. The transformation of traditional rural landscapes into high-value urban development poses long-term risks to community cohesion, weakening the social fabric that sustains strong, interconnected neighborhoods.

Addressing the housing affordability crisis requires a multi-faceted approach involving government intervention, strategic urban planning, and sustainable development policies. Policymakers must implement measures such as incentivizing affordable housing projects, introducing stricter regulations on speculative property investments, and enhancing public infrastructure in peripheral areas to make them more livable and accessible. Sustainable solutions should also prioritize eco-friendly construction practices, mixed-income housing developments, and green urban planning initiatives to ensure long-term affordability while minimizing environmental impact. By addressing these challenges through inclusive housing policies and sustainable urban development strategies, Kuala Lumpur, Selangor, and districts like Hulu Langat can move toward a more equitable and livable future for all residents.

The phenomenon of urban sprawl from Kuala Lumpur into adjacent districts, particularly Hulu Langat, has been a significant driver of property price increases in the region. As Malaysia continues to urbanize, the expansion of metropolitan areas leads to the extension of housing developments into previously suburban or rural districts. Hulu Langat, which was historically known for its agrarian landscape and traditional villages, has undergone substantial transformation due to this urban expansion. The growing population and increasing demand for residential properties have resulted in higher land values, making housing more expensive for local residents.

Urban sprawl occurs when city dwellers and investors seek more affordable housing options outside the congested core of Kuala Lumpur. The influx of new residents, coupled with speculative investments in the property sector, has exacerbated price inflation in Hulu Langat. As more people relocate to the district in search of better living conditions, developers capitalize on the opportunity by constructing large-scale housing projects that cater to the middle- and upper-income groups. This trend has had a cascading effect, driving up the cost of land and property, making homeownership increasingly unattainable for lower-income households. A study examining the impact of urban sprawl on property prices in Hulu Langat found that this outward expansion from Kuala Lumpur has substantially influenced the surge in property prices within the district (Abdullah et al., 2017).

In addition to residential developments, commercial and retail establishments have also followed the trajectory of urban expansion. As business centers, shopping malls, and industrial hubs emerge in previously underdeveloped areas, they contribute to an increase in land values. The economic appeal of these developments attracts investors and property buyers, reinforcing the upward trend of property prices. This has created a situation where demand continues to outstrip supply, further intensifying the affordability crisis in Hulu Langat. Consequently, urban sprawl, while indicative of economic progress, has played a pivotal role in the growing housing affordability issues faced by many residents.

Infrastructure development has been another critical factor influencing property price inflation in Hulu Langat. Major transportation networks, digital connectivity improvements, and energy projects have significantly enhanced the accessibility and attractiveness of the district, thereby driving property values upward. As part of the Malaysian government's national agenda, infrastructure expansion has been prioritized to support the country's rapid urbanization and economic development. The implementation of large-scale projects, including highways, bridges, and public transportation systems, has transformed Hulu Langat into an increasingly desirable location for residential and commercial investments.

One of the most notable infrastructure investments that have contributed to rising property values in Hulu Langat is the expansion of the Kajang-SILK Highway and the Sungai Besi-Ulu Kelang Expressway (SUKE), which have improved connectivity between the district and major employment centers in Kuala Lumpur. Additionally, the extension of the Mass Rapid Transit (MRT) network has further facilitated mobility, allowing commuters to travel seamlessly between suburban and urban areas. These transportation advancements have made Hulu Langat a more accessible and convenient residential location, subsequently leading to an increase in housing demand and property values.

Apart from transportation projects, investments in digital and energy infrastructure have also played a role in shaping the property market in Hulu Langat. The government's initiatives to enhance broadband connectivity, sustainable energy solutions, and water supply infrastructure have improved the overall livability

of the district. With modern amenities becoming more readily available, the desirability of residential properties has increased, pushing real estate prices even higher. The Malaysian government's investments in transport, digital, and energy infrastructure during the Tenth Malaysia Plan (2011-2015) were specifically aimed at meeting rising demand and supporting economic expansion (Economic Planning Unit, 2015). Such developments in and around Hulu Langat have likely contributed to the appreciation of property prices by improving connectivity and stimulating local economies.

Furthermore, as infrastructure projects continue to develop, they attract additional investment in commercial, retail, and industrial sectors. New shopping complexes, educational institutions, medical centers, and business parks emerge as a result of these infrastructure upgrades, fostering economic activity and further reinforcing property appreciation. While these advancements are beneficial for overall regional growth, they also contribute to rising living costs and property price inflation, placing further strain on lower-income groups who struggle to afford housing in the district.

The surge in property prices in Hulu Langat has significantly impacted the *socio-economic stability* of local communities, particularly affecting residents from low- and middle-income backgrounds. As property values continue to rise, many individuals and families find themselves unable to secure housing within the area, leading to forced relocation to more affordable but often less developed regions. This displacement can have long-term repercussions on community structure, weakening established social networks and diminishing the sense of belonging among long-term residents. Studies have indicated that when residents are forced to move due to financial constraints, their social capital is eroded, making it more difficult for them to access local support systems, employment opportunities, and essential services (Abdullah et al., 2017).

Furthermore, the fragmentation of communities due to housing unaffordability can result in increased levels of social isolation and reduced participation in community activities. Traditional neighborhood interactions, which often serve as informal support systems, are weakened when long-term residents leave, thereby diminishing collective efforts in neighborhood security, cultural preservation, and local governance. The influx of wealthier residents who can afford the rising property prices may also contribute to gentrification, further altering the cultural and socio-economic composition of Hulu Langat. This transformation can lead to tensions between different income groups, exacerbating existing socioeconomic inequalities and reducing community cohesion. When residents feel disconnected from their communities, there is an increased risk of social unrest, reduced civic engagement, and a decline in communal trust(Abdullah et al., 2017).

Additionally, housing unaffordability affects access to essential services and economic opportunities. Many displaced residents may have to commute longer distances to reach their workplaces, schools, and healthcare facilities, increasing financial strain and reducing overall quality of life. The need for extensive daily travel due to relocation can contribute to increased transportation costs, time inefficiencies, and heightened environmental concerns, further straining the region’s urban infrastructure and resources. In turn, these challenges can undermine long-term economic growth by limiting the ability of the local workforce to thrive within the area (Habitat for Humanity, 2023).

Ensuring access to affordable housing is fundamental in fostering stable and cohesive communities in Hulu Langat. When individuals and families have secure and affordable living arrangements, they are more likely to engage in community development initiatives, contribute to local economic growth, and maintain social stability. Studies have shown that access to affordable housing directly correlates with higher levels of community engagement, as residents who are not burdened by excessive housing costs can participate in neighborhood organizations, local events, and civic activities, thereby strengthening social cohesion (Habitat for Humanity, 2023).

Moreover, stable housing conditions have been linked to *improved social and economic outcomes*, including better educational performance among children, reduced crime rates, and increased workforce productivity. Affordable housing policies that incorporate sustainable and inclusive urban planning not only help in addressing economic disparities but also enhance the livability and resilience of urban areas like Hulu Langat. Implementing strategies such as incentivizing mixed-income housing developments, increasing government intervention in public housing projects, and enforcing rent control measures can alleviate the financial burden on vulnerable populations and create a more balanced housing market (Abdullah et al., 2017).

Furthermore, *investment in affordable housing can act as a catalyst for broader economic and infrastructural development.* When housing is made more accessible, local businesses benefit from a stable workforce, public transport systems become more efficient due to reduced urban sprawl, and social welfare costs decrease as fewer individuals require government assistance. Ensuring housing affordability in Hulu Langat is not just a matter of providing shelter—it is a critical strategy for building a thriving, resilient, and inclusive community that supports the long-term well-being of its residents (Habitat for Humanity, 2023).

By integrating affordable housing policies with sustainable urban development principles, policymakers and urban planners can mitigate the negative effects of rising property prices and ensure that Hulu Langat remains a socially cohesive and economically accessible region. Encouraging public-private partnerships, leveraging green building initiatives, and promoting long-term investment in rental housing can create a housing ecosystem that serves diverse economic groups while preserving the unique cultural and environmental

characteristics of the area. If these measures are effectively implemented, Hulu Langat can serve as a model for sustainable urban growth, where economic progress is balanced with social equity and environmental responsibility (Abdullah et al., 2017).

Addressing the housing affordability crisis in Hulu Langat and Kuala Lumpur necessitates comprehensive governmental intervention, policy reform, and sustainable urban planning. Policymakers should expand the supply of affordable housing through targeted incentives for developers, increase investments in public housing, and implement regulations to curb speculative property activities (Samad et al., 2016; Khazanah Research Institute, 2019). Measures such as rent control, land value taxation, and stricter oversight of housing markets can reduce volatility and protect lower-income groups. Infrastructure development should be guided by principles of equitable access, ensuring that improvements in connectivity and amenities benefit all income brackets, not just investors. Furthermore, decentralizing economic activities from Kuala Lumpur by enhancing connectivity to peripheral districts like Hulu Langat can relieve pressure on central urban zones, foster regional development, and reduce socio-economic disparities (Bank Negara Malaysia, 2020; Abdullah et al., 2017).

In addition to economic measures, urban planning strategies must emphasize inclusivity, sustainability, and community preservation. The integration of mixed-income housing developments, green infrastructure, and community participation in planning processes can prevent displacement and gentrification (Habitat for Humanity, 2023). Preserving local culture and social networks, especially in historically rural districts like Hulu Langat, is vital for maintaining social cohesion. Regular monitoring of housing policies and socioeconomic indicators should guide policy adjustments to ensure effectiveness. Ultimately, by embedding affordability and inclusivity at the core of urban development, Malaysia can promote equitable growth, reduce urban poverty, and build resilient communities that benefit from the country's broader economic expansion (Economic Planning Unit, 2015; Shuid, 2016).

It is crucial to implement housing affordability solutions for the local people of Hulu Langat because they are among the most directly and disproportionately affected by the rapid urban expansion and rising property prices driven by Kuala Lumpur's metropolitan growth. As land values and housing costs escalate, long-standing residents particularly those from lower- and middle-income backgrounds are facing increasing risk of displacement, financial insecurity, and loss of community identity. Without intervention, these individuals may be forced to relocate to underdeveloped areas with limited access to essential services, employment, and infrastructure, further entrenching socio-economic inequality (Samad et al., 2016; Abdullah et al., 2017).

Moreover, the preservation of social cohesion and cultural continuity in Hulu Langat depends on maintaining stable, inclusive communities. When local populations are priced out of their own neighborhoods, it leads to the erosion of traditional rural landscapes, weakens local economies, and disrupts intergenerational community bonds. Ensuring access to affordable housing enables residents to remain rooted in their communities, contribute to local development, and participate meaningfully in civic life. By safeguarding housing affordability, we not only protect the welfare of Hulu Langat's people but also support long-term regional stability and sustainable urban growth (Habitat for Humanity, 2023; Khazanah Research Institute, 2019).

CONCLUSION

The findings of this research highlight the critical relationship between property price inflation, housing affordability, and community well-being in Hulu Langat, Selangor, within the context of Sub-theme 3: Built Environment Sustainability and Conservation. The rapid escalation of property prices, driven by urban expansion, market forces, and infrastructure development, has intensified socioeconomic disparities, limiting access to affordable housing and disrupting community cohesion. To ensure sustainable urban growth, it is imperative to adopt inclusive housing policies, strategic land use planning, and environmentally responsible development that balance economic growth with social equity. Conservation of the built environment should be prioritized through sustainable construction practices, green infrastructure, and adaptive reuse of existing structures, which can help mitigate the adverse impacts of urbanization while preserving the region's ecological and cultural heritage. By addressing these challenges through data-driven policymaking, targeted interventions, and collaborative efforts between government agencies, urban planners, and community stakeholders, Hulu Langat can transition toward a more sustainable, resilient, and socially inclusive urban landscape. Ultimately, this research underscores the importance of integrating affordability, sustainability, and conservation principles into urban planning frameworks to foster equitable development and ensure long-term livability for future generations.

ACKNOWLEDGEMENT

I am the author of this paper and I want to express my highest gratitude to the Faculty of Built Environment, University Malaya, especially the supervisor for funding this publication.

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ADOPTION OF ARTIFICIAL INTELIGENCE (AI) TOOLS FOR STRESS MANAGEMENT AMONG BUILT ENVIRONMENT STUDENTS

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ABSTRACT

Research shows that there is high indication of stress among built environment students with more than 70% throughout their university life. Although stress is a well-recognized issue among built environment students, existing research has predominantly focused on traditional coping strategies in stress management. To date, no studies have examined the adoption and use of AI tools for stress management among built environment students. This research seeks to address this gap by investigating the role of AI in supporting stress management among built environment students. The fundamental objectives of the study are threefold: first, to identify the adoption level of AI tools in stress management among built environment students; to analyze how AI tools support stress management among built environment students; and to identify the barriers in adopting AI tools for stress management. The research adopts a quantitative technique using Universiti Sains Malaysia as the case study. For data collection purposes, 253 students in built environment are targeted to survey based on Krejcie and Morgan's (1970) sample size table. Descriptive statistics will be used to analyse the data collected, especially using percentages, mean and standard deviation. The significance of this research can help universities make informed decisions about improving student support services using artificial intelligence-driven technologies. By understanding the role of AI in stress management, this research can help to build better facilities and services that enhance student well-being.

Keywords: Artificial intelligence (AI) tools, Built environment students and Stress management.

I. INTRODUCTION

Research by Kamarazaly, M. A. et al. (2021) shows that there is a high indication of stress among built environment students with more than 70% throughout their university life. These results are the same as the research done by Ganesan, Y. (2018), Nurasikin, M., & Shariff. (2021) and Phia, D. W. J., S, V., & Hassan, N. C. (2024), even though their respondents are not built environment students but also university students in Malaysia.

Santos, A. D. dos et al. (2025) and Liu, Z. et al. (2023) highlighted that one of the causes of high stress levels among university students is the academic factor. Besides, financial conditions are also essential contributors to this issue (Nurasikin, M., & Shariff., 2021 and Ding, Y. et al., 2025). Azizi, N. S. M. et al. (2020) discussed that building networks is the primary resiliency factor for built environment students. According to Teh, C. K. et al. (2015), social stress also brings significant impact on the stress level among the university students.

Syed, M. et al. (2023) and Pazil, N. S. M. et al. (2021) as well as Ganesan, Y. et al. (2018) pointed out several positive stress coping strategies that have been taken by university students. Meanwhile, Kamarazaly, M. A. et al. (2021), Ismail, A. et al. (2016), Ganesan, Y. et al. (2018) and Lee, K. W. et al. (2022) concluded that some university students also adopt negative mechanisms to cope with their high stress levels. However, Hj Ramli, N. et al. (2018) stated the opinion that Malaysian university students basically have poor self-regulation and find it difficult to manage their stress well. It would be the primary factor that stress management can be a thorny issue among the university students. This indicates that the strong need of the university students to have an alternative way of coping strategy in managing stress, such as artificial intelligence (AI) tools.

Adrianos Pavlopoulos et al. (2024) and Olawade, D. B. et al. (2024) categorized the AI tools into three types: chatbots, Applications/Apps as well as Wearable Devices. The examples of chatbots include Woebot, Wysa, Tess, ChatGPT and Replika. Besides, Happify, Headspace, Calm and MindShift CBT are common

applications regarding mental health issues. People also wear smartwatches like Apple Watch, Samsung Watch, Garmin, Fitbit as the wearable device to help in monitoring their health and physical situation from time to time.

AI holds immense potential for managing stress, making it impossible to ignore. For instance, ChatGPT is beneficial in stress reduction as it can be used to break down complex tasks into simple steps, aiding the individuals struggling with time management and organization as stated by Imran, N. et al. (2023). Khanthavit, A., & Khanthavit, S. (2023) agreed by proposing that AI such as ChatGPT can help reduce stress by helping to solve certain problems. It is because AI provides a wide range of applications across sectors, such as business applications, digital marketing and education, as stated by Haleem, A. et al. (2022). Melo, A. et al. (2024) summarized in their study that utilising AI chatbots, such as ChatGPT, can bring positive effects to life quality and also well-being.

However, there are barriers arisen while university students adopting AI tools throughout their university life. Firstly, Cheng, R. et al (2024) and Cubric, M. (2020) emphasized that awareness and knowledge barriers play essential role in this case. Hangl, J., Krause, S., & Joy Behrens, V. (2023) agreed with Hussain, T., Wang, D., & Li, B. (2024) that people faced trust and perception issues in the consideration of adopting AI-driven technology. Cheng, R. et al (2024) and Cubric, M. (2020) also pointed out the barriers for AI adoption should include financial barriers as most of the AI tools will require subscription cost for premium version. Hussain, T., Wang, D., & Li, B. (2024) analyzed from their findings that the growing reliance of AI-driven technology during the pandemic has sparked ethical concerns about its deployment and impact with the same idea as Cheng, R. et al (2024) and Cubric, M. (2020). Furthermore, the higher education institutions should be counted as one of the barriers due to their duty to raise the awareness among the students (Wang, L., & Li, W., 2024) & (Benicio, G. A.-E. et al., 2025).

In short, artificial intelligence (AI) is beneficial in mental health, but currently there is not much research investigating it specifically towards stress, particularly among university students. Meanwhile, I found out that most of the research tends to study the stress condition among the medical or nursing university students but neglects the built environment students.

II. LITERATURE REVIEW

A. Stress

World Health Organization (WHO) (2023) and Kementerian Kesihatan Malaysia (2011) explained the definition of stress as a condition of mental strain, such as pressure faced by an individual as a result of an event that happened to them. Stress and mental illness are commonly used interchangeably; however, they are not the same. World Health Organization (WHO) (2023) also clarified that a stressful environment can lead to mental health issues, such as the most common anxiety and depression, which need access to health care. Stress is the typical symptom when we suffer from a mental health condition.

B. Stress Level among University Students

Kamarazaly, M. A. et al. (2021) have done research for analysing the stress level and the coping strategies among the quantity surveying students at Taylor's University. They also highlighted that there was little to no research focusing on the stress level among built environment students, but the majority of the existing studies were related to medical students and engineering students. The different study environment will affect the outcome of the stress level. The result shows that most of the quantity surveying students suffered in moderate stress levels, with 110 students (71%) facing moderate stress among 154 respondents. They also highlighted that the findings are similar to the research done by Ganesan, Y. et al. (2018) at University Malaysia Sarawak. 67 students were having moderate stress among 86 respondents in the Faculty of Cognitive Science and Human Development, UNIMAS. Ganesan, Y. et al. (2018) also concluded that the stress level among the university students is not affected by the gender and ethnicity among the respondents.

C. Artificial Intelligence (AI) in Mental Disorders

Chatbots

Woebot

According to Segaran, S. et al. (2022), Woebot is a commercialized self-help therapy chatbot designed by Alison Darcy, a psychologist, in 2017. Hu, R. (2019) explained that Woebot employs cognitive behavioural therapy (CBT) to assist individuals with managing their mental health. It offers mood tracking, daily evaluations, and targeted conversations. Clinical investigations have indicated that it is beneficial at lowering depression and anxiety symptoms. (Fitzpatrick, K. K. et al., 2017).

Wysa

Wysa is also one of the popular chatbots for enhancing mental health, based on the research by Olawade, D. B. et al. (2024) and Adrianos Pavlopoulos et al. (2024). Segaran, S. et al. (2022) and Inkster, B. et al. (2018) explained that Touchkin developed Wysa, an AI-powered emotional chatbot to promote mental resilience and well-being through text-based conversations. In Malik, T. et al. (2021)'s study, the users of Wysa provided the comments that Wysa provided a secure and open platform for expressing thoughts and feelings. Chang, C. L. et al. (2024) analysed that most of the users adopt Wysa for mindfulness, sleep meditation and guided visualization for seeking mental health support by this application.

Tess

A study by Fulmer, R. et al. (2018) opined that Tess, a psychological AI chatbot created by X2AI Inc., provides short chats for integrated mental health care, psychoeducation, and reminders. Tess is a therapeutic tool that may be used in conjunction with therapy to assist an integrated approach. It is not meant to replace a therapist. Bhattacharya, B. S., & Pissurlenkar, V. S. (2023) shared the claims from X2AI that "Tess has been professionally proven to help people feel better. Chatting with Tess has been shown to lessen feelings of depression (-13%) and anxiety (-18%)." Dosovitsky, G. et al. (2020) and Rauws, M. et al. (2019) stated that a user can sign up for Tess within a minute if he feels down, and he will get the reply from Tess anytime through text messaging (i-Message or SMS) or Facebook Messenger.

ChatGPT

Furthermore, ChatGPT is also an artificial intelligence (AI) chatbot developed by OpenAI. In Kacperski, C. et al. (2023)'s words, ChatGPT provides a forum for people to engage, seek information, or even find companionship through virtual conversation. According to Imran, N. et al. (2023), ChatGPT is beneficial in stress reduction as it can be used to break down complex tasks into simple steps, aiding the individuals struggling with time management and organization. Khanthavit, A., & Khanthavit, S. (2023) agreed by proposing that AI such as ChatGPT can help reduce stress by helping to solve certain problems. It is because AI provides a wide range of applications across sectors, such as business applications, digital marketing and education, as stated by Haleem, A. et al. (2022).

Replika

Come to the next example of the AI chatbot, Replika, which is an AI-based conversational agent (CA) according to Ma, Z. et al. (2024). Syed, M. et al. (2023) demonstrated that users can customise a buddy by selecting a 3D avatar and customising its appearance in this tool. The Replika and the user grow together, developing their personalities and memories. Piispanen, J.-R. et al. (2024) and Ta, V. et al. (2020) described that Replika has its prime function to be a companion to the users by offering the emotional assistance and social support, especially in extremely stressful situations or health-related contexts.

Mental Health Applications

Happify

Montgomery, R. M. et al. (2021) expressed that Happify is a mobile and web-based digital intervention that fosters mental and physical wellness through evidence-based therapies. Parks, A. C. et al. (2018) explored the potential of Happify to build resistance to the future symptoms upon noticing that it is developed not only to diminish negative symptomatology. In Adrianos Pavlopoulos et al. (2024)'s words, Happify offers users engaging activities and games aimed at efficiently relieving stress and combating anxious thoughts. It provides personalised analytics based on an individual's mental health data, ensuring individualised help that meets their specific needs. Users can quickly reach these activities and games at any time they want, allowing for seamless incorporation into their daily routines.

Headspace

Olawade, D. B. et al. (2024) introduced that Headspace is an app for guided meditation and mindfulness initiatives. It employs Artificial Intelligence (AI) to personalise the meditation experience for each user. The Headspace app offers evidence-based, expert-led information such as guided mindfulness, meditation with animations, progressive muscle relaxation, psychoeducation, and gratitude activities. (Callahan, C. et al., 2024). Mindfulness elements may address both basic self-care and particular mental health illnesses including anxiety, stress, and sleep disturbances (Callahan, C. et al., 2024).

Calm

According to Wasil, A. R. et al. (2021), Calm is a mindfulness and meditation application that enables users to develop mindfulness abilities, practice meditation, and track their moods and emotions over time. In Huberty, J. et al. (2019)'s previous study, it stated that Calm provides mindfulness meditation practice guide modules that vary in duration, teaching, and topic. Puzia, M. et al. (2021) also attribute that Sleep Stories featured in Calm present fictional tales that use mindfulness-inspired techniques to increase experiential awareness such as thoughts, positive feelings, sights, and sounds. This disrupts the cycle of rumination and lowers pre-sleep arousal, allowing individuals to fall and stay asleep more effectively.

MindShift

Through MindShift, users take the chance to learn several CBT tactics, like recording a thought journal, completing belief experiments, creating a fear ladder and evaluating their comfort zone (Kwon, H. et al., 2024). Check-ins enable users to track their progress and examine graphs and diaries. Users are guided in setting objectives and receiving reminders. Users may easily export and share data with their therapist, counsellor, or psychologist via email (Kwon, H. et al., 2024).

Wearable Devices

Smartwatches

In Olawade, D. B. et al. (2024)'s words, smartwatches integrating AI algorithms track sleep, physical activity, and heart rate, providing useful data for mental health monitoring. De Zambotti, M. et al. (2019) raised the point that stress can be minimized with high quality of sleep. Smartwatches can help to monitor the sleep duration, periods, and quality so sources of stress and fatigue can be revealed by sleep patterns analysed. Huang, W.-Y. et al. (2022) have another idea that stress can be reduced when exercising. With a smartwatch, it can track steps, distance, calories and workouts. With this, stress can be alleviated by promoting consistent exercise and giving feedback from time to time (Carter, D. D. et al., 2018).

D. Barriers in Adopting AI Tools

Awareness and Knowledge Barriers

According to Cheng, R. et al (2024), a minimal AI adoption stemmed primarily from the lack of awareness and knowledge about how the AI models undertake decision-making processes. Most of the people even do not have idea about the existence of certain types of AI models when they need help to solve their problems.

Cubric, M. (2020) shared that lack of knowledge about AI-driven technology will contribute to the barriers of AI adoption. People do not have sufficient knowledge about the potential capability of AI tools for specific types of problems. They have no idea what types of AI can help them in their life. As a result, they are unable to utilise the appropriate AI models when they are in need.

Trust and Perception Issues

Hangl, J., Krause, S., & Joy Behrens, V. (2023) found out that lack of understanding and trust in AI is also a vital barrier to its adoption. Many people still do not fully understand what AI is and how it can be used, which will cause the trust issue and resistance to adoption. Cheng, R. et al (2024) mentioned that people will have privacy and confidentiality concerns while considering to adopt AI models. Privacy concerns arise from the way AI models keep, access and analyse the user data. They do not fully trust the AI models that may divulge their personal data and cause threaten to them.

Financial Barriers

In Cubric, M. (2020)'s words, the barriers for the AI adoption should include economic aspect, related to the cost using the AI tools. AI models mostly need additional charge to unlock premium version for providing better services, which will cause the economic burden to the users and hesitate to use the AI models, same as the idea of Cheng, R. et al (2024). Strauss, J. et al. (2022) analysed that the AI applications for mental health such as Happify apps requires $ 14.95 for paid version every month while Calm Premium is required to prolong the free trial by paying $69.99 CAD. Those AI tools also provide free versions to the users but with limited functionalities which will lessen the effectiveness of using the AI tools.

Psychological and Behavior Barriers

Psychological and behavior barriers play an important role in the adoption of AI. Hussain, T., Wang, D., & Li, B. (2024) analyzed from their findings that the growing reliance of AI-driven technology during the pandemic has sparked ethical concerns about its deployment and impact. Fear of job losses and dependence on non-humans lead to the barriers for adoption of AI. People do not like too much dependence on robotic helpers instead of human interaction (Cubric, M.,2020). Cheng, R. et al. (2024) concluded that there are concerns of overreliance on AI models as they are worried about the consequence brought by the mistakes in AI-based decision making.

Institutional Barriers

Wang, L., & Li, W. (2024) conveyed that higher education institutions should take the responsibility to stimulate AI technology among the university students by highlight the positive experiences during AI adoption. Generally, the common AI models can help to facilitate active learning, personalized learning methos and strengthen students' digital efficacy and innovative skills. However, the university institutions seldom promote AI tools as the way for stress management, especially in Malaysia. Benicio, G. A.-E. et al. (2025)

demonstrated that AI contributes significantly within higher education institutions through AI maximizes operational efficiency, allowing educators to focus more on teaching and research. It leaves a huge gap for utilizing AI models in handling stress.

III. METHODOLOGY

A. Research Design

The flowchart of research framework is illustrated in Figure 1.0.

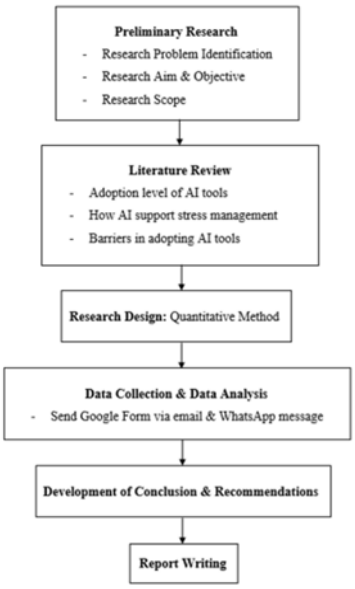


Figure 1.0 Flow Chart of Research

B. Research Method

In this research, the quantitative research method is more matching to be the research approach. A structured questionnaire is designed based on the literature survey. Closed-ended questions are asked for collecting quantitative data. They provide the respondent with a restricted number of choices. Likert scales are simple to employ since the respondent may visually assess how they feel about a certain issue.

C. Research Population and Sample

In this study, the probability sampling methods, simple random sampling is selected. The selection process targeted the university student, particularly built environment students using Universiti Sains Malaysia as case study. This approach aims to delve into the insights about the adoption of AI tools for stress management among the built environment students.

D. Development of Questions

Based on the existing studies, a set of survey questions has been developed for the research purpose. The survey is divided into four sections, which are:

1) Section A –Demographic Information
   The respondents will be asked to give some information about himself/herself such as gender, age, program of study and year of study by answering multiple choice questions.
2) Section B – Stress Level based on Perceived Stress Scale (PSS-10)
   The respondents will need to answer the questions to demonstrate their stress level according to 10 questions in PSS-10.
3) Section C – Adoption Level of AI tools in Stress Management
   The respondent will indicate their responses on the Likert scale according to the frequency of their use of each AI tool.

4) Section D – Usage of AI tools in Stress Management
   The way how the AI tools help in stress management will be explored in this section by measuring the level of agreement with statement about each AI tool, using a Likert Scale.

5) Section E – Barriers in Adopting AI tools in Stress Management
This section delves into the barriers the students face in adopting AI tools for stress management by measuring the degree of agreement with statement related to five proposed barriers, using a Likert Scale.

E. Data Collection

The target of this research is the stressful built environment students in Universiti Sains Malaysia (USM) with various programs. To obtain the data from all the built environments students in USM, the following steps are taken: First, the name list of each year of students in the respective program is confirmed from the office; second, emails that consist of the electronic survey method and links to the web-based questionnaire were sent to them.

F. Data Analysis

Descriptive statistics will be employed for data analysis in this research. In detail, objective 1 of this research will be analysed by frequencies and percentages, determining the number of built environment students using AI tools specifically for each AI tool. Measures of central tendency (mean) will be utilised for data analysis for objectives 2 and 3. By analysing Likert scale responses, the average rating for effectiveness of each AI tool as well as the barriers in adopting those tools will be evaluated. Meanwhile, objective 2 and 3 will be analysed based on standard deviation for better understanding of the spread and consistency of responses. Last but not least, SPSS is an ideal software for the data analysis stage.

CONCLUSION

This study focuses on investigating how deeply AI tools penetrate university students' lives in term of stress management. This study also specifies how the AI tools support stress management and barriers of AI adoption among the university students so that the universities can put more effort on the promoting AI tools for students' better performance.

ACKNOWLEDGEMENT

The author acknowledges the guidance and support provided by the supervisor, Dr. Nurul Sakina Binti Mokhtar Azizi from School of Housing, Building and Planning, Universiti Sains Malaysia, Pulau Pinang.

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THE INFLUENCE OF UNCERTAIN SUBSTRUCTURE DESIGN CHANGES TO CONSTRUCTION COST PERFORMANCE

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ABSTRACT

Substructure design encompasses building foundations and below-ground elements. Despite being a critical aspect of construction projects, substructure designs are often subjected to various changes during construction stage. The changes are often caused by multiple parties due to the uncertainties in soil condition. The uncertainties in substructure design stem from factors like geotechnical variability, environmental conditions, and unforeseen discoveries. Such uncertainties pose significant challenges for project teams to achieve construction performance and efficiency. The changes can disrupt construction activities, such as excavation and building work, leading to project delays, cost overrun and rework. This study aims to explore the causes and effects of uncertain substructure design changes and its effects towards project cost performance. The study outlines two objectives: (1) To identify the causes of changes in substructure design during construction stage, and (2) To identify the effect of changes in substructure design towards construction cost performance. The research employs a qualitative approach by collecting data from interviews with structural engineers and quantity surveyors. The respondents have at least 4 years' experience in designing, constructing, and monitoring substructure designs and its cost implications. The qualitative data collected from the interviews are to be analyzed using thematic analysis. The expected outcomes of this study include a comprehensive understanding of the technical, organizational, and external factors leading to substructure design changes and their direct and indirect effects on construction cost performance. The findings will provide effective actions for mitigating the adverse impacts of design changes, thus enhancing project efficiency.

Keywords: Design Changes, Cost Performance, Substructure Design, and Uncertainty

I. INTRODUCTION

A. Research Background

The substructure, comprising the foundation and other lower supporting elements, transfers the superstructure's load to the earth. It is a critical component of the building, ensuring overall stability and structural safety. The substructure of a building is a vital component that significantly contributes to the overall stability of the structure. Without a properly designed and constructed substructure, the building would be incapable of withstanding the imposed loads and forces, potentially resulting in structural failure. Substructure works often involve some common activities such as excavation, foundation construction, waterproofing installation, and basement construction. Substructure design is essential to assure structural stability and feasibility of the project. Achieving cost effectiveness and timely completion are the main objectives in the construction industry. Nevertheless, the substructure design process is inherently complicated, especially in the post-contract stage, when unexpected issues often require changes in design. A design change refers to any modification in the design or construction of a project that occurs after the contract has been awarded and executed (Boon et al., 2017). Design changes can occur when there are changes in the project design and requirements. After the awarding of the construction project contract, design changes typically involve modifications, such as increases, decreases, or adjustments to the design and construction work. These alterations impact the contractual provisions and construction conditions, resulting in a dynamic and potentially unstable construction process (Kong & Rahman, 2021) .

According to Boon Hui et al. (2017), changes in construction project can be arise due to both external and internal factors. The changes also include design changes. Internal factors can be classified into several types

of causes consisting of client-related causes, design-related causes, and contractor-related causes. For substructure design, the common causes of its changes are usually related to the project specific dynamic such as location and site conditions. Site condition becomes the basis and guideline for the engineer to design the substructure such as foundation and basement construction. Some unforeseen ground conditions such as the presence of underground rock or existing cable and services can cause an engineer to revise the design and conduct a rework to ensure the substructure works can be carried out successfully and stable. As stated by Boon et al. (2017), rework is defined as the additional effort required to repeat a process or activity due to its incorrect implementation during the initial attempt. Most rework instances result from changes, defects, damages, errors, omissions, or other non-conformities.

B. Statement of Problems

During the construction phase, the uncertainties of substructure design can happen due to several causes during the tender preparation stage. One of the main causes is unforeseen subsoil conditions. According to (Lee et al., 2021), The variability and heterogeneity of soil properties represent significant sources of uncertainty in construction planning and risk management. Engineers typically rely on their professional experience and judgment to estimate the overall subsoil conditions based on the limited data obtained from soil investigations. This uncertainty can cause an inaccurate load calculation and unsuitable selection of foundation type.

The uncertainties of substructure design changes can disrupt construction activities such as excavation and piling works. It will lead to significant delays and cost increases. The properties of natural subsurface materials are inherently more complex than analysing man-made superstructures (Lee et al., 2021). When there are uncertainties, the design error may occur. Design error is a mistake or wrong design specification by the engineer related with the specification in the drawing, load requirement and site constructability. Design errors require rework by the designer and result in substructure design changes. The substructure design changes resulting from uncertain soil investigation can create a domino effect where it will also impact on the overall project timeline and budget. The result of the delay can also cause some variations that will lead to limited project resources, disputes between parties and ultimately interrupt the project finance and operational performance.

If the design error is not repaired, the foundation will not be strong enough to support the structure. Without proper management and caution taken into designing a substructure for a building construction, a failure of foundation can occur and the risk of building collapsing. On 28 June 2022, a four-storey building collapsed in Mumbai due to poor structural design, improper structural maintenance and insufficient foundation strength which the tragedy had killed 19 people (Gowthami & Ramesh, 2022). This accident has proved how important the study on the substructure design in construction. The foundation failure also can happen due to the soil settlements which can cause the building to be cracks and unstable.

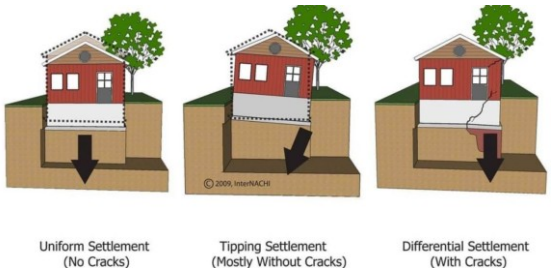


Figure 1.0 Types of Settlements in Foundation

C. Research Objectives

Based on recent issues, the aim of this research is to identify common causes of substructure design changes during construction stage. The exploration of the experiences by construction professionals on these issues will be studied. It also seeks to identify the effects of the changes to address the issues. In order to achieve the research's aim, the following research objectives have been set out:

1. To identify the causes of changes in substructure design during construction stage.
2. To identify the effect of changes in substructure design towards construction cost performance.

Subsequently, the research furnishes deeper understanding on how the design changes in substructure works is managed and how the project team control the impact of it. The intense information obtained through this research would also provide a good reference for other researchers to do further research on relevant topics.

II. LITERATURE REVIEW

A. Importance of Substructure Design in Construction

Substructure design is crucial to the overall success of any construction project due to its role in ensuring stability and transferring loads to the ground. Its importance becomes particularly evident when considering the potential impact of design changes, especially during the construction stage. Ajator & Ugochukwu (2015) emphasized that the substructure of a building is designed to serve several essential purposes. One of the primary functions of the substructure is to enhance the stability of the structure. As the base of the building, the substructure directly influences the project's structural integrity and safety. Errors or uncertainties in substructure design can compromise the entire building. Therefore, it is imperative that engineers adhere to proper procedures and apply appropriate methods during the design process.

When designing substructure elements such as foundation, engineers must consider both geotechnical and structural factors, including load conditions and foundation movement. As outlined in the (*Chapter 7 Substructure Design - WSOT Bridge Design Manual*, 2024), designers must exercise good judgment in selecting the controlling load conditions to optimize the design. Additionally, all anticipated dead load conditions should be accounted for during substructure design. For geotechnical considerations, designers are encouraged to involve qualified geotechnical experts early in the design process to assist in selecting the appropriate foundation type. The design process should address issues related to strength, serviceability, and movement, particularly uneven settlement.

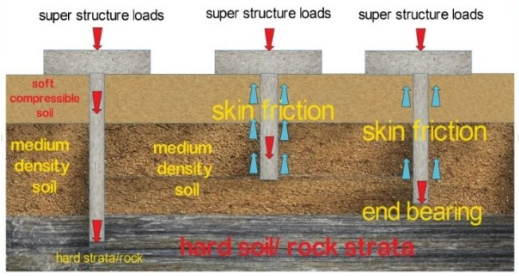


Figure 2.0 Load Movement and Soil Friction

B. Uncertainties and Challenges of Substructure Design

One of the main uncertainties in substructure works is the heterogeneity of ground conditions. According to Lee et al. (2021), variability in soil properties introduces significant uncertainties to construction planning and risk management. In Malaysia, the ground is predominantly composed of tropical residual soils, which are highly variable in their properties. Sia & Abdul Razak (2021) highlighted that one of the biggest challenges in ground conditions in the Klang Valley is the limestone formation, which can pose hazards such as risks of collapse and sinkholes. The varying soil conditions also result in differing vertical and lateral characteristics within the subsurface soil profile Abija (2023).

A lack of geotechnical information is a significant concern when designing substructures such as foundations. Geotechnical information is obtained through geotechnical investigations, which involve exploring surface and subsurface conditions (Sia & Abdul Razak, 2021). Designing a substructure requires knowledge of geological conditions and the stress characteristics of soil and rock. Without sufficient information, the accuracy of foundation design can be decreased. Lee et al. (2021) stated in his study that engineers often rely on their experience and judgment to create assumptions about ground conditions based on the limited information obtained from soil investigations. Unexpected ground conditions can introduce major risks to construction projects, particularly in areas such as cost estimation, construction materials, project coordination, and cost control (Awosina, 2017).

C. Common Causes of Design Changes

Design changes can occur based on two major groups which are internal factors and external factors. Iqbal (2020) highlighted that internal factors are **client**, **consultant**, **contractor,** and **project**. While the **external factors** are such as government policy changes, economic conditions, and problems with the community. A study conducted by Yap & Skitmore (2018) concluded that there are five significant causes of design changes in building projects. The five causes are lack of coordination among various professional consultants, changes of requirements and specification, addition or omission of scopes, discrepancies in design documents, and unforeseen ground conditions. The classification of design changes related causes is important to identify which parties or areas that distribute the most on the design changes.

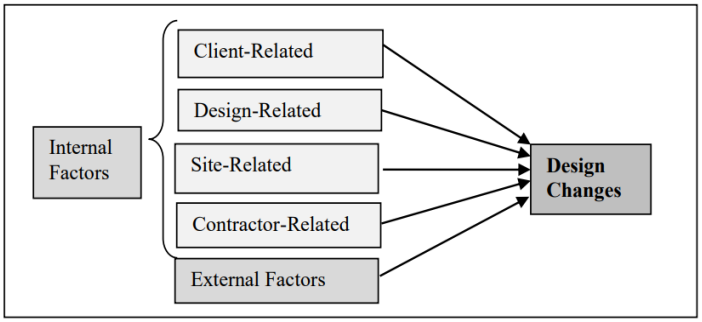


Figure 3.0 Internal and External Factors of Design Changes

According to Yap et al. (2016), **client-related** design changes refer to modifications requested directly by the client or their representatives. Studies indicate that a significant portion of rework occurs due to alterations in plans, or the scope of work initiated by clients. Clients are considered the primary contributors to design changes and hold the authority to propose or approve design modifications based on their requirements and satisfaction. There are three main causes of client-driven design changes: modifications to the initial design, the addition of new work or scope, and incomplete initial design briefs.

For **design-related** causes, any construction project requires effective communication between the client and design team members to produce an accurate design and its specifications. Yap et al. (2016) highlighted that a lack of communication and coordination between the client and engineers can result in errors and omissions during the design documentation process. Studies suggest that fostering a harmonious relationship between the client and engineers can improve the design process and reduce the likelihood of design changes. Factors contributing to design changes include the unforeseen natural growth of the project during the design stage, incomplete or poor-quality drawings, inadequate briefs, design errors and omissions, and uncertainties related to subsurface conditions (Suleiman & Luvara, 2016).

Contractor-related design changes can occur under various circumstances, such as requests for variations due to material availability or preferred construction methods. Contractors often propose alternative methods to save time, correct mistakes or defects, and improve the quality of work on-site (Yap et al., 2016). They may also request modifications to construction methods to better suit current site conditions. Other factors contributing to design changes by contractors include poor site or project management skills, delays in appointing subcontractors and their associated tasks, lack of skilled workmanship and productivity, and inadequate logistics control.

For **project-related** causes, the factor usually involves site and ground conditions that were unforeseen during pre-construction stage. As mentioned by Yap & Skitmore (2018), site-induced causes are such as unforeseen ground conditions or geotechnical issues, site safety considerations like site access, issue with adjacent properties, and undetected underground utilities. Unforeseen problems and various site conditions are one of major causes for design changes as the geotechnical information is not accurate and uncertain (Mishra & Aithal, 2022).

C. Direct and Indirect Cost Implications of Design Changes

Firstly, when the design changes occur, the **rework** must be carried out. Rework can be referred as the effort of re-doing a process that was inaccurate implemented at the beginning stage of design. Boon et al. (2017) mentioned that rework can considered as one of the biggest concerns in construction project and may arises due to changes, damages, defects, error and omission of design. Some of works are redesign for change in quality, redesign for increase and decrease of quantity, and redesign for change in scope (Mishra & Aithal, 2022). Due to rework of design changes, the **delay** of construction project can occur. Delay often occurs due to the unanticipated incident that affect the performance of certain activities under the contract. In project management, the identification of work sequences and critical path is important to analyse which activity can contribute to the delays. When these activities require some changes and rework, the demand of labor, material, equipment hence it will increase the time required for the activity to be complete.

The most concerned effect of design changes is **cost-overrun**. According to Muhamad & Mohammad (2018), the most common impact of design changes increases in project costs and delays in completion. The discrepancies and frequent design changes are one of the huge factors in cost-overrun and failure to achieve a successful project. During construction, design changes due to client requirement may lead to increases of total project value from 5% to 8% (Boon et al., 2017). This is because the designer may require additional cost and resources to re-design and re-doing the activity and require time to get the design approval. Design changes also can cause **loss of productivity** especially when there is additional work and demand on the equipment and labor. Generally, project changes can affect the performance including the labor efficiency (Boon et al., 2017).

The rework, delay in payment, dispute between owner and contractor, suspension of work may lead to the decrease in productivity (Makebo & Elsaye, 2020). When there is no proper of management of design changes, it will disrupt work at site and affect the sequences of work which result in weak productivity (Muhamad & Mohammad, 2018). Lastly, the design changes may cause a **construction dispute** between project team. When rework increases, the total cost increase which will lead to excessive claims and disputes (Boon et al., 2017). This will totally affect the whole project performance and project team must find a way to mitigate overruns and possible disputes due to design changes and rework.

III. RESEARCH METHODOLOGY

This research places a qualitative emphasis, prioritizing the data collection through semi-structured interviews with construction professionals who have experiences on managing substructure design changes during construction especially structural engineers and quantity surveyors. This approach may assist on a deeper understanding of the issues of uncertain substructure design changes including its causes and effects to the construction cost performance.

Literature review is conducted to provide comprehensive and details understanding of how substructure work play its role in the construction including the function of components like foundation, piles and column stump. It shall give a better understanding of how crucial the substructure design is to overcome any uncertainty that may lead to the design changes and therefore cause negative impacts to the project team. Some articles, books and journals related with the substructure design from website such ScienceDirect are taken as references on getting some inputs for the issue.

The information required to achieve the objectives includes the causes and effects of substructure design changes during the construction stage. The type of interview suitable for this study is semi-structured interviews with individuals involved in construction projects which have issues on substructure design changes. Semi-structured interviews consist of several structured questions posed to respondents, followed by related questions that help the researcher gain a deeper understanding of the answers provided.

For data collection, the interview form shall be prepared with several questions that related with research objectives. The questions will be divided into two section which are Section A and B. For Section A, the question given will be focused on experiences of substructure design changes including the causes of design changes, how the issues are managed and what are their roles and responsibilities. While the Section B focuses on how the changes impact other activities in construction and toward cost performance such as additional claims and disputes. The recommendation and strategies on overcoming design changes are expected to be given by the respondent. The duration for the interview is expected to be 40 minutes to 1 hour via online platform like Google Meet.

The respondent will be determined and approached by using website of The Institution of Engineer Malaysia (IEM) and Board of Quantity Surveyor Malaysia (BQSM) to determine the status of the company. The respondent will be approached through LinkedIn to determine the experiences and company of the professionals. The are only two kinds of respondents are approached to gain different perspectives on the issue of substructure design changes occur during construction. Firstly, the structural or geotechnical engineer which are the responsible team on designing the substructure and provide a judgement on the method selection. Secondly, quantity surveyor from consultancy team as they are forecasting the cost implication of any changes or variations including the additional cost due to variation order and control the budget by the client.

Once the recordings are collected, the interview will be transcribed for the coding purpose by using Nvivo software. The data will be coded and analysed to identify the categories or themes of causes for substructure design changes and their impact on construction cost performance. Data analysis techniques that are employed in this study is thematic analysis which is used to organize and analyse qualitative data. The analysis will assist the researchers in summarizing the findings and providing recommendations for further studies on substructure design changes during the construction stage.

Lastly, the research will be concluded to summarize all the findings and analysis from research background to the data analysis. It will also include the recommendations on overcoming the design changes of substructure which can be considered for further study.

IV. EXPECTED FINDINGS

The expected outcomes will help shape the framework of this study. The exploration on the causes of substructure design changes with the construction professionals will be highlighted in several themes and classifications. The causes of substructure design changes may be divided into several related factors due to each project team members and also external factors. The construction professionals that can majorly be involved in design changes are clients or employers, consultants and contractors. The themes may provide better insight into the parties that are responsible for the issue of design changes and how they are managed by other stakeholders.

While the effects of substructure design changes towards project cost performance will be divided into direct and indirect cost implications. This is because both cost implications will significantly contribute to the cost performance index (CPI) which is one major indicator on success of a project. Some direct costs including cost of materials, machinery and equipment, additional skilled workers, and loss and expenses by contractor. While indirect cost may relate with delay of project, additional professional fees and suspension of work. This finding will be combined with the roles of every party involved and the strategies suggested by the respondents to address issues in the future of substructure design management.

CONCLUSION

In conclusion, design changes in substructure design can happen due to many stakeholders and project teams. Soil properties and ground conditions become a main uncertainty for the engineer to determine the suitable substructure design. While the rework and design changes may impact the project cost performance. An exploration of the current issue of substructure design changes towards the project cost performance will provide insight into the management of the uncertainty of substructure works in Malaysia.

The next level of research would be able to identify the ways and techniques to eliminate the uncertainty in the substructure and identify some strategies to avoid any cost overrun due to design changes in substructure which can lead to poor performance of construction and cause high expenditures. While all the stakeholders, including clients, consultant team and contractors, shall improve the cooperation and make a good communication to find the best mitigation plan to manage the design changes due to any circumstances.

ACKNOWLEDGMENT

The main author would like to express his gratitude to Building Surveying Department of UiTM Perak branch, especially the supervisor for funding this publication

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ASSESSMENT OF COMMON BUILDING DEFECTS AND CONSERVATION TECHNIQUES IN ROYAL HERITAGE BUILDINGS: A STUDY ON RESTORATION PRACTICES

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ABSTRACT

Restoration is defined as a process of repairing something to its original condition while conservation is a practice of preserving and maintaining something to prevent deterioration. The royal heritage building is meant to represent something priceless like a symbol of history, traditional architecture, and national identity. Dissimilar to other common buildings, the royal buildings need special attention because it belongs to royal family such as Istana Mangga Tunggal in Pekan, Pahang and Galeri Diraja Sultan Abdul Aziz in Klang, Selangor. Factors like weather changes, building age, and lack of effective maintenance may cause defect to the building that requires immediate restoration and conservation efforts. This study aims to observes types of building defects occured at the royal heritage buildings. This will assess the level of severity on the defects to the buildings. Then, the most appropriate method will be proposed as the second objective. On this study, a qualitative method has been implemented consist of interviews, site observation and document analysis. However, 5 respondents has been selected for the pilot study to collect preliminary data which are among Quantity Surveyor, Contractor, Authority, Curator and Consultant. In conclusion, while the Department of National Heritage has established guidelines for the restoration and conservation of buildings in the royal town, certain processes may be modified or bypassed due to royal decrees. These adjustments help accelerate the restoration while ensuring the preservation of the royal heritage for future generations. Hence, at the end of the research, a usable framework will be proposed.

I. INTRODUCTION

Historical and cultural heritage in Malaysia is largely reflected through royal heritage buildings. Besides being recognized as physical structures, these buildings represent national pride in heritage and identity. Since they involve unique historical structures, improper preservation may lead to prolonged damage. The conservation process of royal heritage buildings is a crucial step in ensuring the continuity of aesthetic, historical, and cultural values.

The National Heritage Department emphasizes that conservation efforts require a comprehensive understanding of internationally accepted conservation concepts. This includes both scientific research to determine the extent of damage and the authenticity of building materials, as well as the principle of minimal intervention to the original structure. In addition to restoring the physical features of the building, conservation aims to maintain the integrity and authenticity of heritage buildings.

Furthermore, the Public Works Department of Malaysia (JKR) highlights that conservation involves several key phases, including obsolescence surveys, comprehensive documentations, and the creation of transparent tender documents to ensure accurate work scope and cost estimation. Similarly, to ensure that the chosen strategy does not compromise the structural strength or historical significance of the building, preliminary studies and damage assessments are essential.

In addition, the conservation of heritage buildings is not only meant to preserve historical and cultural values but also to ensure safety and durability for future generations. This principle indirectly involves minimal disruption to the original structure and the application of scientific research to assess damage and the authenticity of building materials (National Heritage Department).

Based on Malaysian legislation and guidelines, the National Heritage Act 2005 (Act 645) serves as a legal framework for heritage building conservation. The National Heritage Department is responsible for the registration of National Heritage sites and the implementation of conservation projects across the country (Khairul H. Kamaruddin, 2019).

1.1 Research Background

In Malaysia, royal heritage buildings symbolize the grandeur of the royal institution and serve as a source of national pride. Royal architecture exemplifies how this artistic heritage has been passed down through traditional methods, colonial influences, and modernity, as seen in structures such as Istana Sultan Abu Bakar (Pekan, Pahang) and Istana Seri Menanti (Kuala Pilah, Negeri Sembilan). These buildings function as royal residences, administrative centers, and venues for official ceremonies. All of this enhances their significance as historical and cultural landmarks. To preserve history, maintain symbolism, attract tourists, and strengthen national identity, these heritage structures must be conserved.

Furthermore, these historic structures represent distinctive architectural styles that incorporate regional materials such as zinc roofing and cengal wood, along with unique features like multi-tiered roofs and intricate carvings. However, environmental threats such as humidity, erosion, climate change, and other factors endanger the original construction of many heritage buildings in the country. The National Heritage Department asserts that these issues have worsened, requiring immediate action to preserve the elements that are historically deteriorating these structures.

Therefore, research in this context should assess the extent of damage and propose potential intervention strategies based on globally accepted standards such as the Venice Charter and the Burra Charter. Such an approach is necessary to meet contemporary needs like safety and accessibility while preserving the authenticity and integrity of heritage buildings without compromising their physical form.

1.2 Problem statement

Material deterioration, inadequate maintenance, and environmental considerations are some of the causes of structural deterioration in royal heritage buildings. To ensure their long-term preservation, this study aims to identify critical building defects that could ultimately lead to collapse. Figure 1 shows some building defects happened to heritage buildings such as cracks and peel of paint.



Figures 1.0 Cracks and peel of paint at Sultan Abdul Samad building

Malaysia is home to many heritage buildings, many of which have suffered damage due to various factors such as the age of the buildings, weather changes, and poor maintenance. For example, historical buildings like Sultan Abdul Samad have experienced severe building defects (The Star, 2024). The defects include ceiling collapse and significant moisture effects. According to The Star (2024), these defects are caused by weather changes and modifications in building usage, leading to abandonment and increasing deterioration. This building has been abandoned over 20 years. The confusion of ownership affects the maintenance management of the building. Khairul Kamarudin (2013) has highlighted that moisture-related damage can cause wood decay and insect infestations, such as termites attacking the roof and wall structures. The UNESCO World Heritage site shows that Heritage buildings in Georgetown, Penang are facing rapid degradation that brought on by environmental pressures such as humidity and pollution. This is caused by the changes as well as neglect. Nur Rahull et al (2024) states that common defects such as cracks, moisture and peeling paint threaten their structural integrity.

Furthermore, the lack of knowledge about heritage building conservation is a critical issue in Malaysia. Abdul Rahman (2011) states that the country still lacks technical experts and skilled workers to carry out conservation work on valuable heritage sites. Additionally, there is a shortage of professionals in heritage city management and an overlap between heritage city conservation and tourism development.



Figure 2.0 Crack on artifact in Kota A Famosa, Melaka

Moreover, vandalism in heritage buildings is becoming increasingly widespread due to the lack of proper conservation, leading to the deterioration of these structures. For instance, in the historic A Famosa fortress in Melaka as shown in figure 2, vandalism has caused cracks in artifacts within the building (Sinar Harian, 2023). There are challenges in conservation efforts such as selecting the appropriate conservation technique. Heritage conservation principles emphasize the authenticity of materials and traditional procedures, which often conflict with modern methods. This makes it difficult to determine a suitable and effective conservation approach. Hence, a thorough investigation is required to identify efficient and appropriate conservation techniques for historic structures.

1.3 Research objectives

The objective of this project is to ensure that the preservation of these structures is systematic and effective. To achieve this goal, the study aims to:

a. To observe types of building defect needed for the royal heritage buildings.
b. To determine the appropriate methods for conserving the royal heritage buildings.

II. LITERATURE REVIEW

At this stage, some information has been drawn from previous research findings related to the topic. However, the discussion now focuses on the most pertinent subtopic, offering deeper exploration and analysis.

2.1 Introduction

The current research on restoration and conservation of Royal Heritage building is examined in this overview of the literature Harun. S.N (2023). It focused on exploring the important theories, methods and conclusion from the various investigations. This study attempts to identify trends, gaps and for additional research (Maria Antonia, 2023). This includes by synthesizing the body of available information. In order to provide a thorough overview and guide future study and practice, the review is divided into several parts.

2.2 Definition

The following are some key descriptors used in this study. The next definition to be covered is whether heritage is tangible or intangible (Rahull et al, 2024)

2.2.1 Heritage and Historic Buildings

Heritage refers to something inherited by individuals or communities from one generation to the next. According to the National Heritage Department (2019), heritage encompasses everything valuable that is passed down from one generation to another. This includes printed documentation in the form of books and papers, as well as attitudes, culture, locations, buildings, and documents. It also can be categorized into tangible and intangible forms. A historic building refers to a structure or a collection of buildings that are either independent or interconnected and are characterized by their architectural significance, uniformity, or their place within the landscape. These buildings hold outstanding universal value in terms of history, art, or science (National Heritage Department, 2009).

2.2.2 Conservation

Conservation refers to the actions taken to preserve and restore history, culture, and the environment from physical changes. A simple definition of conservation is the intention to prevent harm, damage, or destruction (Rohayu Roddin, 2019). According to the National Heritage Department, the most universally accepted and practiced concept is "Authenticity in Heritage Conservation." Authenticity is considered not only in terms of aesthetics but also as an ethical process of restoration (National Heritage Department, 2019). In this context, the goal of conservation is to protect existing heritage so that it can continue to be appreciated by future generations without experiencing unnecessary damage, deterioration, or destruction (National Heritage Department). Conservation not only involves the physical aspects but also the historical and cultural values associated with the objects or buildings under conservation.

2.2.3 Building defects

Building defects refer to a failure function for the entire building. This failure influenced by internal factors and external factors. Yacob et al (2019) mentioned that building faults are an issue that most structures encounter. It is the independent of building techniques or age and it all relies on the causes and contributing factors.

2.3 Types of building defect

The heritage value, aesthetics, and functionality of royal heritage building are often compromised due to frequent exposure to various forms of deterioration. There are two main causes of deterioration: internal and external factors according to Omar Mostafa Alomari (2022).

Table 1.0 External and Internal factor of building defects

A	**External Factor**	**Examples of picture**
1.	Climate changes	
2.	Pollutions	
3.	Natural disaster	
4.	Urban developments	
B	**Internal Factor**	**Examples of picture**
1.	Ventilation issue	
2.	Unregulated alterations	
3.	Natural material deterioration	
4.	Flaws in structural design	

2.5 Conservation Methods of Royal Heritage Buildings

Effective conservation techniques are necessary to preserve the architectural and historical relevance of royal heritage buildings. One important conservation technique is adaptive reuse, which prolongs the life of historic structures while maintaining their cultural significance by re-purposing them for contemporary functions without changing their original design. This method, which the government frequently use to turn important homes into museums, guarantees relevance while abiding by conservation regulations. Another important tactic is maintenance, which includes regular checks, fixes, and environmental management to stop little problems from becoming more serious and causing extensive damage. In accordance with UNESCO and National Heritage Department (2019) conservation guidelines, ongoing care protects the structural integrity, safety, and aesthetic value of historic buildings.

III. METHODOLOGY

In this research there are a few methods that have been adopted for the data collection process. This study focuses on qualitative methods which include observations, document analysis, and case studies for objectives one while semi structured interviews for second objectives. This process is described as follows.

3.1 Case Study

The researcher has chosen 3 buildings from 3 different state for the case study which are Istana Mangga Tunggal in Pekan, Pahang, Istana Seri Menanti in Kuala Pilah, Negeri Sembilan and Galeri Diraja Sultan Abdul Aziz in Klang, Selangor. During the observations, the researcher used a checklist to assess and document the severity of building defects. The form is shown in figure 3.0

3.2 Site Observation

A checklist was used to evaluate the severity of building defects observed on-site, categorized as mild, moderate, or severe. These classifications were determined based on the researcher's justification, supported by references from previous studies. Figure 4.0 shows the progression of structural defects through different types of cracks. For example, hairline cracks are thin and superficial, often emerging due to minor settlement or temperature shifts. Moderate cracks are wider and deeper, hinting at potential foundation movement. At the most critical level, severe cracks are large and deep, directly compromising the building's structural integrity and requiring urgent action.

Check list

Date : 22/1/2025

Time : 10.10 a.m - 4.00 p.m

Location : Istana Kesultanan Melaka, Bandar Hilir, Melaka.

No	Component	Mild	Moderate	Severe	Notes
A	**Wall**				
	Cracks				
	Breakage				
	Wear marks on the surface				
	Fungal growth, moss, algae or peeling paint.				
	Termite infestation				
B	**Floor**				

Figure 3.0 Example of checklist



Figure 4.0 Example of severity level

3.3 Semi-structured Interview

There are 15 targeted respondents needed to achieve the objective which includes the consultant, authorities, contractor, curator and site supervisor. However, 5 respondents have been involved in the pilot study for preliminary data collection, which are Curator, Quantity Surveyor, Landscape & Recreation Consultant, Architect Consultant and Contractor. They are from Department of National Heritage, Landscape and Recreation Department at Majlis Pembandaran Pekan (MPP), Jabatan Muzium Negeri Johor, University of Technology Malaysia and Selasih Padu Sdn Bhd respectively. During the semi-structured interview session, open-ended questions were used, allowing participants to freely express their opinions. The sessions took placed at respondent's office for about 2 hours to be completed. The semi structured interview questions were divided into three sections, as shown in Table 2.0 below:

Table 2.0 Interview Questionnaire Design

Section	Content
A	General Information: Includes demographic details such as organization, age, gender, job position, and work experience.
B	To observe types of building defect needed for the royal heritage buildings: Focuses on observations and analyze document for building defects.
C	Identifying suitable conservation methods for royal heritage buildings: Aims to gather feedback from respondents on the best conservation methods.

3.4 Document Analysis

The analyzed documents included research papers on historical buildings, conservation guidelines, government regulations related to heritage buildings conservation, and previous studies. They were selected based on their relevance to the study objectives and their availability. Priority was given to documents dated within the last 10 years and directly related to heritage building.

IV. PILOT STUDY DATA AND FINDINGS

The pilot study revealed consistent patterns of physical deterioration, with observable surface and structural defects that emphasize the urgency for targeted restoration interventions in royal heritage buildings.

4.1 Data and Findings

The data analyze from the site observation and document analysis conducted in February 2025, it can be observed that mostly cracks and peels of paint are common building defects occurred at historical buildings. These defects are frequently caused by the weather, moisture ingress, a lack of proper maintenance, and material deterioration over time. From the observation and document analysis the crack appears on walls and column due to structural movement and thermal expansion while the peel of paint appears on walls due to prolonged exposure to humidity.

Other than that, from the semi-structured interview session, the output from the respondent has been concluded as follows, to preserve authenticity and longevity, royal heritage building must be conserved by substituting comparable materials. To increase solidity, traditional wall plaster once formed of eggshell and lime while with modern technology, it is now replaced with cement and mortar. It is similar for wooden structures where resak is used instead of cengal wood. This is because the strength between cengal and resak wood is almost similar. Thus, before resak is being used there will be material testing conducted before the applications. Other than that, to maintain the original design, roof tiles are meticulously replicated. For example, there is one famous Mosque in Terengganu where the building was taken apart and put back together using the same components and original layout. This demonstrates that cultural heritage may be conserved without losing its core characteristics. Hence, the make good approach reduces the need for contemporary replacements that can compromise authenticity by reinforcing the buildings with existing materials.

Besides that, the compliance with the royal decrees will also affect the procedures. Due to his command the variation order might be occurred and affecting the overall project cost. The conservation procedure for royal heritage buildings is different from non-royal projects. This is because the involvement of Your Highness preferences is based on his hobby, activities, favourite colour and observation during his visits to foreign country influence the decision on choosing building material and colour of the building. Your Highness must formally approve any conservation or restorations efforts, which might speed up the procedure. The royal decrees are the topmost priority for the completion of a project. Faster approvals are made possible by official letters of consent. Hence, this project will be prioritize over normal project. Furthermore, the process of handing over royal projects entails traditional ceremonies, such as an official opening and inspections by the Your Highness before, during and after the restoration.

CONCLUSION



Figure 5.0 Framework of conservation to Royal Heritage Building

In conclusion, even though there are guidelines that have been developed by authorities such as Department of Public Work (JKR) and also Department of National Heritage (JWN), due to the power of Your Highness, these procedures can be exempted in order to fulfill its royal decrees. Thus, to honor Your Highness rank as Head of State Government, the authorities are required to uphold and enforce his royal decrees without exception. Hence, Your Highness project would finish in shorter time compared to normal building without having to comply with the initial plan. Besides, Your Highness power guarantees that conservation initiatives are in line with historical relevance and traditional values in addition to expediting permits.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to my supervisor, Dr Farah Nadiah Binti Abdul Rahim, for her invaluable guidance, support, and encouragement throughout this project. Her insights and expertise have been instrumental in shaping my research, and I truly appreciate her dedication. I also would like to express his gratitude to Building Surveying Department of UiTM Perak branch, especially the supervisor for funding this publication.

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RISING TO THE CHALLENGE OF MANAGING PASSENGER HOIST PERFORMANCE IN HIGH-RISE CONSTRUCTION PROJECTS

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ABSTRACT

Managing passenger hoist performance during peak hours is critical for ensuring operational efficiency and worker safety in high-rise construction projects. Delays and inefficiencies in hoist operations during peak times can lead to significant productivity losses and safety risks, affecting overall project timelines. This research aims to identify the key factors contributing to these challenges and explore best practices for optimising passenger hoist management. A qualitative research approach will be employed, utilising structured interviews with key construction stakeholders, including project managers, site engineers, and safety officers. By systematically examining these factors, this study seeks to fill the gap in existing research on vertical transportation inefficiencies during peak hours. Additionally, it contributes to construction management literature by providing empirical insights into the challenges of managing passenger hoists in high-rise projects. The study's practical contributions include recommendations for improving scheduling strategies, workforce coordination, and maintenance practices to reduce delays and enhance safety. The findings will serve as a reference for construction professionals and policymakers in developing efficient hoist operation frameworks that mitigate congestion, improve reliability, and enhance site productivity. Furthermore, this research will support future studies on high-rise construction logistics and technological advancements in hoist management, ensuring better industry practices and compliance with safety standards. The expected outcomes include a deeper understanding of operational challenges and data-driven solutions that can be implemented across various construction projects. By addressing the inefficiencies in passenger hoist operations, this study aims to enhance the overall functionality and sustainability of vertical transportation in high-rise developments, contributing to safer, more productive, and cost-effective construction environments.

Keywords: Efficiency, High-Rise Construction, Passenger Hoist, Scheduling, Safety

I. INTRODUCTION

Managing passenger hoist performance during peak hours in high-rise construction projects is critical to ensuring operational efficiency and worker safety. As urban development trends toward taller buildings, the demand for effective vertical transportation solutions has never been greater. Passenger hoists serve as essential equipment for transporting workers, tools, and materials between various floors of a construction site, particularly during busy periods when multiple trades require simultaneous access to hoisting services.

Over the past decades, there has been a significant shift from on-site work to off-site manufacturing in the construction industry, which means that a large portion of construction work is now pre-fabricated in factories and assembled on-site. However, off-site work is not traditionally considered a part of the construction industry but a sector under manufacturing. The impact of new technologies does not necessarily mean that these industries are more productive from a total productivity point of view. However, they may trade off labour for automation without overall benefits or even expend on technology (Eastman and Sacks 2008). Construction productivity is significantly underestimated because off-site work is typically ignored when evaluating productivity.

II. LITERATURE REVIEW

Passenger Hoist in Construction Site

Passenger hoists are essential vertical transportation systems in high-rise construction, facilitating the movement of workers, tools, and materials between floors. Their efficiency directly impacts project timelines, safety, and productivity. Peak hours, such as morning shifts and lunch breaks, often lead to congestion and delays due to high demand. Common challenges include equipment malfunctions, inadequate scheduling, and workforce coordination. Best practices for managing passenger hoists include regular maintenance, operator training, automated scheduling tools, and real-time monitoring systems. By addressing inefficiencies and adopting advanced technologies, construction projects can enhance safety, reliability, and overall operational efficiency in high-rise environments.

Key Factors Causing Delays and Inefficiencies in Managing Passenger Hoist

Effective management of passenger hoists during peak hours is critical for maintaining operational efficiency and worker safety in high-rise construction projects.

Human factors play a significant role, with issues such as poor workforce coordination, inadequate operator training, and miscommunication leading to scheduling conflicts and congestion (Huang & Liu, 2018). Technical factors also contribute, including equipment malfunctions, insufficient maintenance, and the use of outdated hoist technology, which reduces reliability and operational performance (Ali et al., 2019)

Environmental factors, such as adverse weather conditions, space constraints, and site-specific challenges, can further disrupt hoist operations and increase delays (Wong et al., 2019). Peak traffic patterns, particularly during the start and end of shifts and lunch breaks, exacerbate these issues, requiring optimised scheduling strategies to mitigate congestion (Huang & Liu, 2018). Addressing these factors necessitates a comprehensive approach that integrates scheduling optimisation, technological upgrades, and enhanced workforce management (Liu et al., 2020).

Best practices for Managing Passenger Hoist Operations

Effective management of passenger hoists in high-rise construction requires a multifaceted approach, beginning with meticulous planning. Detailed hoist schedules should account for peak traffic patterns to minimise congestion and optimise usage (Rahman et al., 2020). Control is crucial, with real-time monitoring systems enabling project managers to track hoist performance and dynamically adjust schedules based on actual demand and site conditions. Ensuring clear responsibilities and competence through proper training and certification of hoist operators is essential for safe and efficient operations (Yusof & Ismail, 2018).

Maintaining reliable equipment through regular inspections and proactive maintenance prevents malfunctions, while investing in modern hoist technology enhances overall performance and safety (Lee et al., 2021). Rigorous inspection, maintenance, and certification protocols must be followed, ensuring all hoists comply with safety regulations. Finally, a comprehensive management system should integrate hoist operations with overall project logistics, using data-driven insights to improve performance continuously. By implementing these best practices, construction projects can significantly enhance the efficiency, safety, and reliability of passenger hoist operations, leading to improved project outcomes (Tan et al., 2019).

III. METHODOLOGY

The research design employed is qualitative method. This approach utilises semi-structured interviews with key construction stakeholders, including project managers, site engineers, and safety officers, to gain a deeper understanding of managing passenger hoist performance during peak hours in high-rise construction projects.

The research unfolds in several key stages. First, a comprehensive literature review is conducted to establish a theoretical foundation and identify research gaps. Second, the research objectives and questions are defined to guide the study. Third, the interview instrument is developed, pilot tested and refined to ensure validity and reliability. Fourth, semi-structured interviews are conducted with construction professionals to gather rich, qualitative data. Finally, the collected data is analysed to identify key themes, patterns, and insights related to passenger hoist management.

Instrument Development

The instrument development process centred on creating an interview protocol tailored for gathering detailed data on passenger hoist management within high-rise construction projects. This protocol was structured to include sections addressing demographic information, key factors contributing to delays and inefficiencies, and best practices for optimising hoist operations, particularly during peak hours. The interview questions were carefully crafted to explore human, technical, and environmental factors impacting hoist performance, as well

as aspects like planning, control, assignment of responsibilities, equipment maintenance, inspection procedures, and overall management systems. The primary goal was to collect rich, qualitative data from key stakeholders such as project managers, site engineers, and safety officers, enabling the identification of significant challenges and effective strategies for optimising passenger hoist management, especially during periods of high demand.

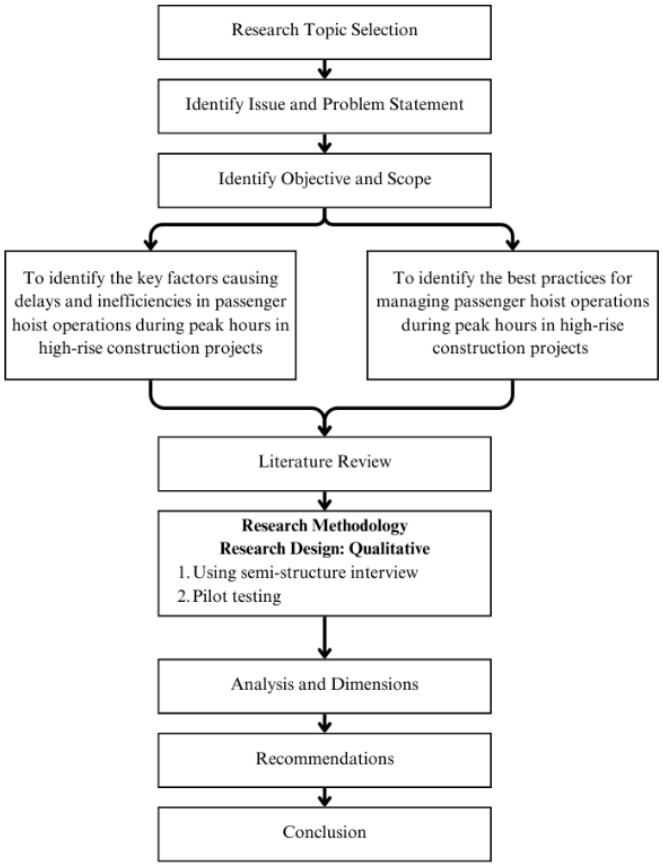


Figure 1.0 Research Methodology

Population and sampling

The population for this study comprises professionals directly involved in passenger hoist management and operation within Malaysian high-rise construction projects. This includes project managers, site managers, safety officers, hoist operators, and subcontractors, each offering crucial perspectives on hoist performance, particularly during peak hours.

Participants were selected using purposive sampling, ensuring the inclusion of individuals with specific knowledge and experience relevant to passenger hoist operations. Criteria for selection included active involvement in hoist operations, at least two years of experience in high-rise construction, and participation in ongoing Malaysian projects utilising hoists during peak hours. A target sample size of 10–12 participants was set to achieve data saturation and capture a range of perspectives, ultimately enhancing the reliability and relevance of the collected data.

Data analysis method

The data analysis method employed in this research follows a qualitative approach, focusing on the rich insights gathered from semi-structured interviews with experienced construction professionals. This method allows for a deep exploration of the challenges and best practices in managing passenger hoists, particularly during peak hours, within high-rise construction projects.

The data analysis process involves several key stages. Initially, all interviews are transcribed verbatim to ensure accuracy and detail. The researcher then immerses themselves in the data through repeated readings of the transcripts, fostering a comprehensive understanding of the interview content. Following familiarisation, a systematic coding process is undertaken to identify recurring themes, patterns, and relevant concepts directly linked to the research objectives. These codes are subsequently grouped into broader, overarching themes that

represent the study's major findings. Finally, these themes are carefully interpreted in relation to the research questions and existing literature, leading to the formulation of well-supported conclusions and practical recommendations.

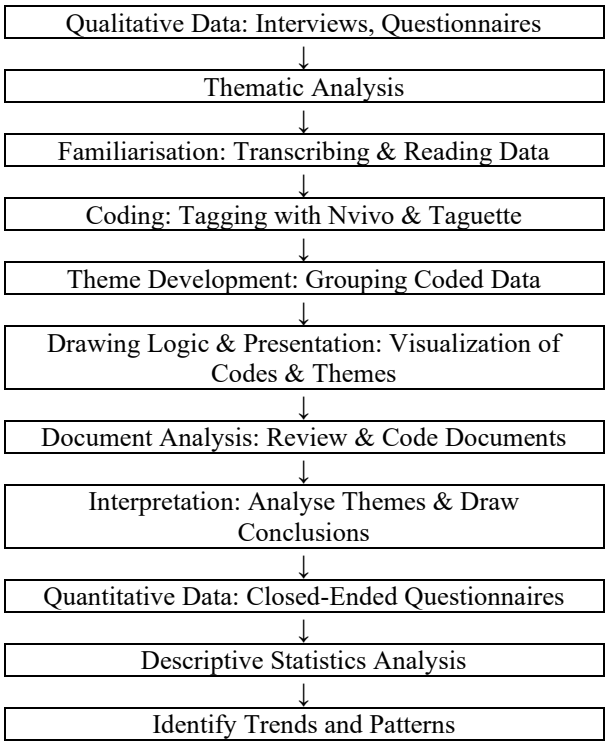


Figure 2.0 Data Analysis Method

CONCLUSION

In addressing the complexities of high-rise construction, effective management of passenger hoist operations during peak hours emerges as a critical determinant of project success. The focus on passenger hoists stems from their pivotal role in facilitating the vertical transportation of workers, tools, and materials, particularly during the busiest periods of the construction day. These peak times often coincide with the start and end of work shifts, as well as lunch breaks, leading to heightened demand for hoist services. This surge in demand can strain the system, resulting in delays, congestion, and potential equipment malfunctions that ultimately impact project timelines and worker safety.

This research aims to explore and understand the operational challenges that arise from managing passenger hoist performance, especially during peak hours. By investigating the multifaceted factors contributing to inefficiencies and identifying best practices for optimisation, the study seeks to enhance the overall effectiveness of vertical transportation systems within high-rise construction projects. The insights gained have the potential to contribute to safer, more productive, and cost-effective construction environments, ultimately benefiting construction professionals and policymakers alike. By providing a framework for improved hoist operation, this research supports the ongoing advancement of industry practices in high-rise construction logistics and the integration of technological innovations in hoist management.

ACKNOWLEDGMENT

This research acknowledges the Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia for supporting this research.

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ASSESSMENT OF CARBON EMISSIONS FROM LANDSCAPING PRACTICES AT THE UNIVERSITY OF READING MALAYSIA: A COMPARATIVE COST ANALYSIS OF ALTERNATIVE SOLUTIONS

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ABSTRACT

Global warming continues to escalate, driven by industrial development and human activities, leading to severe environmental consequences. Rising sea levels contribute to flooding, increasing temperatures create hotter environments, and food and water crises are becoming more pressing challenges. In Malaysia, carbon dioxide emissions accounted for 82% of total emissions in 2017, highlighting the urgency of carbon emission assessments. In response, the Low Carbon Society Blueprint for Iskandar Malaysia 2025 outlines strategic measures to mitigate emissions and promote sustainable urban development. This study will align with Measure 2 of the Blueprint, aiming to integrate green landscape design into low-carbon cities as a strategy to enhance energy efficiency and thermal comfort. The research will focus on the University of Reading Malaysia (UoRM) campus as a case study in Iskandar Puteri, investigating the sources and levels of carbon emissions within its current landscape layout. Using an experimental analysis approach, this study will quantify carbon emissions and sequestration within the campus environment, employing internationally recognized carbon assessment equations. A quantitative research approach will be adopted, collecting data from various campus locations, including trees, transportation, car parks and open spaces to evaluate carbon emissions. The study will also propose alternative landscape methods, assessed through a cost-comparative analysis, to determine the most effective and economically viable sustainable measures. Cost data will be sourced from reputable cost databases, industry suppliers, and contractors, ensuring accuracy in cost feasibility and estimation assessments. By identifying carbon emission sources and recommending cost-effective mitigation strategies, this study will support the implementation of the Low Carbon Society Blueprint within university landscapes. The findings will provide valuable insights for campus and urban sustainability policies, demonstrating the long-term benefits of sustainable landscaping and reinforcing the role of educational institutions in promoting environmental responsibility.

Keywords: Assessment, Carbon emission, Cost Analysis, Landscape, Sequestration.

V. INTRODUCTION

According to the European Union (2024) and the British Geological Survey (2024), the primary sources of global warming are greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases, with CO_2 being the largest contributor. Human activities, including fossil fuel combustion for electricity, deforestation, nitrogen-based fertiliser usage, aerosol sprays, power distribution, and refrigeration, are identified as major contributors. Figure 1.0 shows cumulative CO_2 emissions from 1751 to 2020, with Malaysia contributing less than 1% (6.1 Gt) compared to the USA (417 Gt, 25.21%) and China (236 Gt, 14.27%) (MIDA, 2023). Despite historically low emissions, Malaysia' shift to a manufacturing and service economy since 1957 has increased emissions, with the energy sector contributing nearly 80% in 2019, followed by waste (8%), industry (8%), agriculture (3%), and LULUCF (Ministry of Economy, 2021).

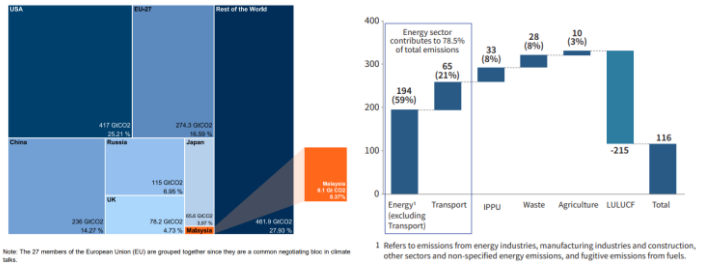


Figure 1.0 CO_2 emission of developed countries in the world (Left: Loong Y.S., 2022) and the percentage of emission of by Sectors in Malaysia (Right: Ministry of Economy, 2023).

Reduced green spaces further limit CO_2 absorption. In response, Malaysia launched low-carbon initiatives like the Iskandar Puteri project, aiming to reduce 1,203 kt CO_2 emissions by 2025 via green infrastructure and carbon monitoring (KASA, 2021 and UTM-Low Carbon Asia Research Center, 2013). One key strategy is sustainable landscape design to improve energy efficiency and thermal comfort at the University of Reading Malaysia. Therefore, this research will focus on identifying key carbon emission sources and critically evaluating potential landscape management practices and their cost implications for implementation at the University of Reading Malaysia (UoRM).

1.1 Problem Statement

Nikologianni et al. (2022) highlighted the lack of effective carbon calculation methods and analysis tools for assessing CO_2 emissions from constructed landscapes and open spaces, limiting the practicality of sustainable landscape practices in addressing climate issues. This research seeks to address this gap by assessing carbon emissions from landscaping practices at the University of Reading Malaysia (UoRM) and identifying suitable calculation methods to accurately reflect current emission levels. Additionally, there is limited research linking landscape planning to carbon emission impacts particularly in terms of 'zero carbon' and 'low carbon' landscape strategies (Nikologianni and Albans, 2023). This study aims to fill that gap by analysing how landscape practices at UoRM can contribute to carbon reduction. Furthermore, Hu. M and Miroslaw. J.S. (2021) identified deficiencies in current sustainable construction cost analysis, particularly in pricing accuracy and cost frameworks. This study will incorporate cost analysis of alternative sustainable solutions beyond landscape practices, applying improved costing frameworks to enhance financial efficiency for green projects at UoRM.

1.2 Aims and Objectives

The aim of this research is to quantify carbon emissions from Landscaping Practices at the University of Reading Malaysia (UORM). The study will conduct a comparative cost analysis of alternative landscape solutions. The research will be evaluating how the landscape within UoRM campus can contribute to capturing and mitigating carbon emissions from the environment. To achieve this aim, the following objectives have been set for the experimental studies:

(a) To quantify the total amount of carbon emission within the campus.
(b) To measure the quantity of carbon sequestration by trees and grassland on the existing landscape design.
(c) To investigate different type of alternative solutions to mitigate carbon emission.
(d) To compare the cost for constructing the landscape practices with its practicability and functional use in terms of reducing carbon emission.

This study will focus on current carbon emission trends, the structural orientation of the University of Reading Malaysia (UoRM) campus, and the analysis of existing landscaping practices. It will also examine and compare the carbon sequestration efficiency based on previous studies with on-site experiment. Additionally, a comprehensive cost analysis of current landscape practices and alternative sustainable solutions will be conducted to support the research objectives.

VI. LITERATURE REVIEW

Sustainability is defined as meeting present needs without compromising the ability of future generations to meet their own, ensuring that current development and technological advancements do not negatively impact the environment or deplete natural resources (United Nations,1987). Achieving sustainability involves three key mechanisms: promoting social and environmental innovation to enhance quality of life, ensuring equitable

prosperity among developing countries, and protecting the environment through responsible practices. Damico A.B. et al. (2022) further reinforced the concept by Hafizyar and Dheyaaldin (2019), emphasising the need to balance economic growth, environmental protection, and social well-being to achieve sustainable development. Green building concepts was introduced in Malaysia to address the issues of climate change and global warming, there are several initiatives that the country took such as green building index, industrialised building system and commitment towards 2030 of 40% of carbon emissions. There is only one green educational campus in Malaysia which is Heriot Watt University Malaysia, Putrajaya. A sustainable campus focuses on addressing environmental concerns while maintaining a balance between environmental, social, and economic aspects within the university setting (Dawodu A. *et al.,* 2022). Dawodu A. *et al.* (2022) further emphasised that sustainable campus goals align with SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), and SDG 17 (Partnership). These SDGs are reflected in real initiatives, such as the University of Glasgow' (2024) Scottish Wider Access Programme and partnerships with educational charities and local councils for student mentorship, and Sunway University efforts in sustainable urban management and green space development.

2.1 Carbon Emission Quantifications Technique

Nikologianni A. *et al.* (2022) highlighted that applying landscape concepts of carbon metabolism and neutrality through careful material selection can support sustainable spaces, aligning with the low-carbon city development approach by UTM–Low Carbon Asia Research Center (2013) and Iskandar Regional Development Authority. However, Zhou Y. *et al.* (2021) questioned the practicality of carbon footprint formulas due to weak links between land use activities and actual carbon emissions. Nikologianni A. *et al.* (2022) further stressed the absence of standardised tools for carbon calculation. To address these gaps, Labaran et al. (2022) recommended evaluating direct and indirect carbon emissions using global standards and frameworks such as IPCC Guidelines, GHG Protocol, ISO 14064-1, and RICS methodologies. Kiehle J. (2023) also stressed the importance of classifying GHG sources for better assessment of carbon neutrality in landscape designs. Direct emissions are defined by Vertes AA. *et al*. (2020) as emissions from fossil fuel sources, primarily transport and manufacturing, while indirect emissions, according to Zhan X. *et al.* (2018), arise from electricity distribution used to power buildings and operations outside the control of the immediate user.

2.2 Emission Factor

Emission Factor (EF) is a default quantity which could demonstrate on the direct amount of the emitted gasses (or pollutants) to the specific activity carried out by the medium with the unit measurement of mass of gas pollutant emissions by the unit of activity associated with production of pollutants (Colbert-Sangree T., 2022). The default data shown in Table 1.0 for quantifying carbon assessment of outdoor landscape practices at University of Reading Malaysia (UoRM), Iskandar Puteri, is supported by the Ministry of Natural Resources and Environmental Sustainability (2024), which provides Malaysia-specific default data. This contrasts with Nnene O. et al. (2023), who did not reference government-specified data. However, the emission factors (EF) provided by the Ministry align with previous studies, reflecting Malaysia' adoption of the IPCC 2006 Guidelines. Colbert-Sangree (2022) further highlighted the widespread use of the IPCC Emission Factor Database (IPCC EFD) for both national and project-level carbon emission calculations, covering direct and indirect emissions.

Table 1.0 The emission factors of different types of sectors associated with various type of fuel type classifications for each respective GHG (Nnene O., et.al.,2023).

Sector	Fuel type	CO_2 (Kg/TJ)	CH_4 (Kg/TJ)	N_2O (Kg/TJ)
Road transport	Motor Gasoline	69,300	33	3.2
	Gas/Diesel Oil	74,100	3.9	3.9
Water transport	Motor Gasoline	69,300	7	2
	Gas/Diesel Oil	74,100	7	2
Air transport	Jet Kerosene	71, 500	0.5	2
Off Road	Gas/Diesel Oil	74, 100	4.15	28.6

2.3 Carbon Storage and Sequestration

Jat M.L. *et al.* (2022) defined carbon storage or sequestration as the natural or artificial process of capturing carbon pollutants from various emission sources and storing them within terrestrial ecosystems composed of biotic elements (plants, animals, microorganisms) and abiotic components (soil, water, air) (National Geographic, 2025 and Michigan State University, 2025). Vegetation, particularly forest areas, acts as natural

'carbon sinks' by absorbing more CO_2 than they release (Client Earth Communication, 2020). Figure 2.0 shows that fruit trees not only provide food security but can sequester between 0.42 to 0.65 Pg of carbon annually, with above- and below-ground biomass (ABG & BGB) storing over 40% of the carbon stock. This is supported by FAO and the Intergovernmental Technical Panel on Soils (2021), which reported 44% of carbon stored in living biomass and 10% in deadwood and litter. However, Chen K. et al. (2024) emphasized that sequestration rates vary by tree species, influenced by climate, temperature, precipitation, and soil conditions. Hasegawa T. et al. (2024) further stressed the importance of selecting appropriate forest types-tropical, temperate, or boreal-based on local climate to maximize carbon storage without degrading land quality (World Wildlife Fund-UK, 2025).

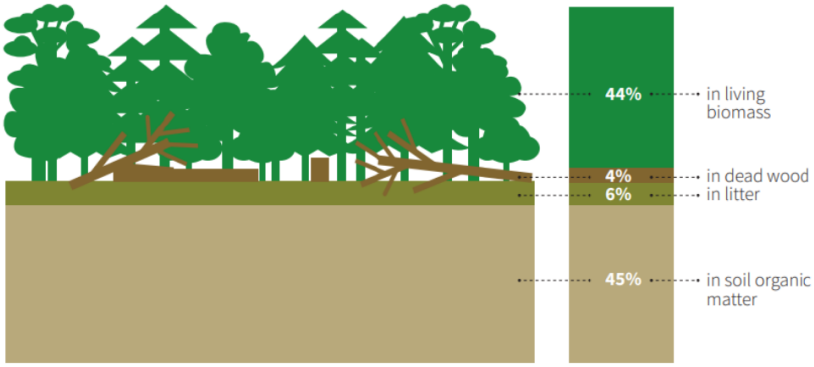


Figure 2.0 the proportion division of biotic breakdown on the forest layout (Food and Agriculture Organization of the United Nations (FAO) and Intergovernmental Technical Panel on Soils, 2021).

Lázaro-Lobo A. *et al.* (2023) highlighted insufficient data on carbon sequestration differences between native and non-native trees, essential for corporate climate decisions. Anantsuksomsri A. *et al.* (2024) stressed ongoing monitoring due to environmental factors. As the GHG Protocol lacks specific sequestration methods (WBCSD & WRI, 2004 and IPCC, 2003) guidelines are recommended. MyCREST (CIDB & JKR, 2020) applies similar biomass calculation steps, estimating carbon content at 47% of dry biomass (Adedotun A. *et al.,* 2024).

2.4 Sustainability approaches on landscaping

Rehana S. and Krishna U.M. (2023) emphasized that sustainable landscaping is vital to prevent ecosystem damage from anthropogenic carbon emissions. Wang W. *et al.* (2023) defined green roofs as sustainable features that lower surrounding temperatures by up to 6°C and roof temperatures by 13.89°C (U.S. EPA, 2024). Beckwith et al. (2022) and Altay E.E. and Batman Z.P. (2024) advocated planting native species to conserve water, enhance habitats, and reduce maintenance. Trees also improve soil stability and sequester carbon, with New York' urban trees storing 1.35 million tons annually (NZILA, 2024). Xeriscaping further supports sustainable water use (World Economic Forum, 2023). Hu M. and Skibniewski M.J. (2021) highlighted unclear terminology in defining sustainable building costs, emphasizing inclusion of materials, labor, and equipment. Goh C.S. *et al.* (2023) showed that sustainable technologies reduce energy use by 26%, GHG emissions by 33%, and increase building value and occupancy but warned of high upfront costs affecting ROI. Wainaina P. *et al.* (2020) recommended cost-benefit analysis for sustainable landscapes. In Malaysia, Ismail H.B. *et al.* (2023) identified cost estimation challenges, including price fluctuations and labor issues, with market price changes ranked highest. Iqbal S. *et al.* (2024) reported similar cost uncertainties in Pakistan' sustainable construction sector.

VII. METHODOLOGY

This study shall adopt a quantitative data collection approach to obtain real-time numerical data for comparison and analysis. Primary on-site, data will be supplemented by secondary data from previous studies to compare emissions between landscaped and non-green areas. For cost analysis, secondary data from credible sources will estimate costs of alternative mitigation strategies. Tree species, planting distance, and campus building stability will be considered, alongside case studies and government reports to ensure the feasibility of proposed strategies.

A primary quantitative approach will be applied through real-time vehicle observation within UoRM, supported by Yaacob N.F.F. *et al.* (2020) and Kabit M.R. *et al.* (2022), who recommended on-site observation over subjective surveys. Additionally, a deductive research approach will be used, following Kabit M.R. *et al.* (2022), by applying calculation formulas to quantify emissions and assess carbon storage based on observed data and existing standards.

3.1 Sampling Location and Characteristics.

The University of Reading Malaysia (UoRM) is situated within the EduCity development area, with a security checkpoint at the main entrance regulating all vehicle access to the student residences, university campus, and other facilities. Three main travel routes and divisions of UoRM' landscape layout should be identified, along with their respective legend colour codes. UoRM occupies a total land area of 69,175.91 m², of which 37,616.72 m² is designated as landscape green land, representing 57.38% of the total campus area. This significant proportion of greenery aligns with the recommendations by Muhiddin *et al.* (2023), who highlighted the need to maximise green space within university campuses to strengthen eco-biodiversity and promote sustainability practices.

3.2 Carbon Emission Quantification Technique.

3.2.1 Average Weekly Streetlight Consumptions

The research direction examines carbon emissions from streetlight energy consumption at UoRM. Lighting accounts for 19% of global electricity use, with street lighting contributing 8% (Chang Y. et al., 2021). As electricity is fossil fuel-based, streetlights indirectly emit carbon. Lighting contributes nearly 5% of global GHG emissions, potentially increasing without intervention (Climate Group, 2025 and UNFCCC, 2025). This study will analyse UoRM' outdoor landscape lighting over a three-month period, focusing on car parks, entrances, and vehicle routes. Key factors include lamp specifications, operational hours, and lighting patterns. Carbon emission quantification for Streetlight operation in UoRM will be calculated using Udoakah Y. et al. (2019) as in (1) and (2).

$$Energy\ (kWh/year) = \frac{Wattage\ (w) \times operation\ hourper\ day}{1000} \times 365\ days \qquad (1)$$

To calculate the electricity consumption of streetlight operations at UoRM, the first step is to identify the wattage of each streetlight (in watts). The second step involves estimating and observing the daily operation hours of the outdoor lighting system (in hours per day). Once this information is obtained, the total energy consumption can be calculated using the energy equation recommended by the U.S. Department of Energy (2025).

$$Carbon\ Emission = Energy\ (kWh/year) \times Emission\ Factor\ (kg\ CO_2/kWh) \quad (2)$$

The next step is to determine the carbon emission per kWh based on the electricity grid' emission factors ((kg CO_2/kWh). These factors can be obtained from the Sustainable Development Centre, University of Malaya (2024) for CO_2 emissions, and from the International Energy Agency (2021) for CH_4 and N_2O emission factors. Finally, the total carbon footprint of the outdoor lighting system will be calculated using the carbon emission equation recommended by the U.S. Environmental Protection Agency (2023).

3.2.2 Average Weekly Traffic Flow Computational

The study will focus on land transportation, as motor vehicle emissions from gasoline combustion significantly contribute to carbon emissions, potentially increasing by 305% by 2050 without mitigation (Yaacob N.F.F. *et al*., 2020). Vehicle emissions depend on type, model, fuel, and usage patterns. Accordingly, vehicle carbon emissions at UoRM will be observed over 14 weeks during Semester 1, 2024/2025, excluding weekends, exceeding Kabit M.R. *et al.* (2022) one-day study. This extended observation aligns with World Meteorological Organization (2024) recommendations for long-term monitoring to identify emission trends. For Category 7 Employee Commuting under Scope 3 emissions, organizations first assess if emissions impact the supply chain without direct control (WRI and WBCSD, 2013).

3.2.3 World Resource Institute and World Business Council for Sustainable Development

The Technical Guidance for Calculating Scope 3 Emissions by WRI and WBCSD (2013) supplements the GHG Protocol to help organizations identify emission sources within their value chain. For UoRM, staff and student commuting falls under Scope 3, Category 7: Employee Commuting, as transportation is not directly controlled by the university (WRI & WBCSD, 2013). To assess emissions over a 3-month period (≈98 days), the guidance requires data on travel distance, fuel type, and Emission Factors (EF) for CO_2, CH_4, and N_2O to support carbon analysis and mitigation strategies (WRI & WBCSD, 2013). Carbon emission quantification for transportation in UoRM will be calculated as in (3) and (4).

$$Total\ distance\ travelled\ by\ vehicles\ type$$

$$= \sum(daily\ one - way\ distance\ between\ home\ and\ work\ (km) \times 2 \times number\ of\ commuting\ days\ per\ year) \quad (3)$$

$$kgCO_2e\ from\ employee\ commuting\ = \sum(total\ distance\ travelled\ by\ vehicle\ types\ (vehicle - km) \times Vehicle\ specific\ emission\ factors\ (kg\ CO_2e/vehicle - km)\ + \sum(quantities\ of\ energy\ consumed\ (kWh) \times emission\ factor\ for\ energy\ sources\ (kg\ CO_2e/kWh) \quad (4)$$

3.3 Carbon Storage on Landscape Analysis.

Average of trees carbon storage quantification: The carbon storage analysis at UoRM will assess tree species using Google Earth mapping and the Malaysia Carbon Reduction & Environmental Sustainability Tool (MyCREST) (The Institution of Engineers Malaysia, 2025). Key parameters include Diameter at Breast Height (DBH) and Above-Ground Biomass (AGB) (CIDB & JKR, 2020). TAGB measures total above-ground vegetation weight (Forest Survey of India, 2021), with DBH recorded at 1.37–1.5 m height (City of Portland Urban Forestry, 2025and CIDB & JKR, 2020). Carbon sequestration for trees $\geq 28\ cm$ diameter in UoRM will be calculated as in (5), (6) and (7) and trees $< 28\ cm$ diameter in (8), (9) and (10).

Tree diameter $\geq$ 28 *cm*

Total Carbon

$$Total\ Carbon = Total\ Biomass\ \times 0.47 \quad (5)$$

Carbon Coefficient for Open Grown Tree in City

$$CarbonCoefficient\ for\ Open\ Grown\ Tree\ in\ City\ = Total\ Carbon\ \times 0.80 \quad (6)$$

Carbon Sequestration

$$Carbon\ Sequestration = CarbonCoefficient\ for\ Open\ Grown\ Tree\ in\ City\ \times (44/12) \quad (7)$$

Tree diameter $<$ 28 *cm*

Total CO_2 Weight (TCO_2W)

$$TCO_2w = TCW \times 3.6663 \quad (8)$$

TCW= Total Carbon Weight

Total CO_2 Weight per year (TCO_2W/ year)

$$TCO_2w/year = \frac{TCO_2}{Age\ of\ Tree} \quad (9)$$

Total tonne of CO_2 Weight per year equivalent ($TtCO_2e$)

$$\frac{TtCO_2e}{year} = \frac{TCO_2W}{2204.62} \quad (10)$$

(a) Average of grassland carbon storage quantification: Besides calculating carbon storage from trees based on height and DBH, MyCREST guidance recommends including grass, shrubs, and groundcovers in carbon analysis to provide a comprehensive assessment, as grasslands also capture and store carbon (CIDB & JKR, 2020). Therefore, UoRM' carbon analysis will adopt the suggested format to measure carbon sequestration rates from these landscape elements, supporting a holistic evaluation of outdoor carbon storage potential (CIDB & JKR, 2020). MyCREST recommends including grass, shrubs, and groundcovers in carbon accounting as they contribute to carbon capture (CIDB & JKR, 2020). For UoRM, Total Dry Weight (TDW) is calculated by multiplying the landscape area by 0.56, then by 0.427 to obtain Total Carbon Weight (TCW). TCW is multiplied by 3.6663 for Total CO_2 Weight (TCO_2W) and divided by 1000 to convert into tonnes (CIDB & JKR, 2020).

VIII. EXPECTED FINDINGS

The expected findings of the conducted experimental analysis in UoRM will give an overall insight into the quantity of carbon dioxide emitted by the identified sources of pollutants and the amount of carbon dioxide sequestration by the identified exiting trees observed that are available in UoRM. Due to the observation duration is only 14 weeks ($\approx 3\ months$) on the amount of carbon dioxide emission and the results will only have a portion of overviews, but the obtained findings will be multiplied by 4-month interval as to estimate the annual quantity of carbon dioxide emission. After calculating the amount of carbon dioxide emission via formula equation proposed by various guidelines, most appropriate guidelines or standards will be selected as the base data for UoRM. On the other perspective, various alternative methods other than the existing measures applied in UoRM for sustainable landscape practice will be identified with its benefits, functionality and

practicability to be applied in UoRM. Comparison will be carried out in terms of payback period, passive income or profit generated, cost-effectiveness and the ability of other alternative methods to reduce the amount of carbon dioxide by carbon offsetting or carbon sequestrating.

CONCLUSION

Overall, it is significantly importance and essential to address the practice of sustainable measures in UoRM as one of the steps to become the sustainable campus in Iskandar Puteri and to respond to the call by UTM-Low Carbon Asia Research Center (2013) to achieve the agenda breakdown stated in Low Carbon Society Blueprint for Iskandar Malaysia 2025 in creating resilience green landscape as one of the importance measures to reduce carbon emission by 3% (≈392 kt CO2eqkt CO2eq) in Iskandar Puteri, Malaysia. Other than achieving the local governmental agenda, by integrating solar panel rooftop installations, solar streetlight installation and planting alternative native trees in UoRM will not only achieve the concepts of sustainable campus, yet will be achieving the SDGs of SDG 4 *(Quality Education),* SDG 11 *(Sustainable Cities and Communities)* and SDG 17 *(Partnership)*. However, there is no limitation on achieving of any goals of SDGs although it is suggested on the primary focus should be on the three of the SDGs as recommended in previous. With the implementation of sustainable measures in UoRM, it could encourage other educational institutions not limited to primary schools, secondary schools, other HEI or even the household communities to implement the similar ways of sustainable measures to work hand in hand in achieving the carbon net zero target suggested in Paris Agreement by 2050.

ACKNOWLEDGMENT

The main author would like to express his gratitude to School of the Built Environment, University of Reading Malaysia, especially the supervisor for funding this publication.

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CONTRACTOR PERSPECTIVES ON BIM (3D, 4D AND 5D) FOR SUSTAINABLE CONSTRUCTION TO ACHIEVE ESG GOALS IN JOHOR, MALAYSIA: ADOPTION, BARRIERS, AND STRATEGIC SOLUTIONS

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ABSTRACT

Building Information Modelling (BIM) has become a transformative technology for advancing sustainability and Environmental, Social, and Governance (ESG) goals in the construction industry. However, BIM adoption among Grade 7 (G7) contractors in Malaysia remains limited, hindered by challenges such as high implementation costs, lack of expertise, and insufficient regulatory support. To address this gap, this study will investigate the adoption levels, barriers, and strategic solutions for implementing 3D, 4D, and 5D BIM in sustainable construction among G7 contractors in Johor, Malaysia. This research will conduct a comparative analysis of BIM adoption strategies in leading countries such as the UK, US, and Singapore, identifying key gaps in Malaysia's current implementation framework. The study will examine the impact of financial constraints, technical limitations, and policy shortcomings on BIM adoption while exploring potential enablers, including government-driven initiatives, financial incentives, and the development of standardized BIM guidelines. A quantitative research approach will be employed, with data collected through structured surveys distributed to G7 contractors. Mean scores analysis will be used to analyse the relationships between key adoption factors. Additionally, barriers to adoption will be assessed using the Severity Index (SI) and strategic solutions will be ranked using the Relative Importance Index (RII) to identify the most critical challenges and most effective interventions. A correlation coefficient (r) will be used to determine the relationship between barriers and strategies. The findings of this study are expected to highlight that policy reinforcement, industry-wide training programs, and mandatory BIM implementation in public projects will be essential to accelerating adoption. By addressing existing barriers and leveraging international best practices, this study aims to propose a comprehensive roadmap for BIM integration in Malaysia. The insights gained will provide valuable recommendations for policymakers, industry stakeholders, and construction professionals, supporting a more sustainable, technology-driven, and globally competitive construction sector in Malaysia.

Keywords: BIM, ESG, contractor, Sustainable

I. INTRODUCTION

The construction industry drives economic growth but is a major contributor to carbon emissions, energy use, and waste (Ibrahim et al., 2010; Bahramian & Yetilmezsoy, 2020; Lima et al., 2021). In Malaysia, it contributes 24% of national carbon emissions and ranks 30th globally (Rahim et al., 2023; Zaini et al., 2020). As sustainability gains global focus, ESG frameworks are increasingly used to measure corporate responsibility and environmental impact (Eccles & Serafeim, 2013; Friede et al., 2015; Roukoz & Ersenkal, 2023). BIM supports ESG by promoting transparency, efficiency, and compliance (Markopoulos et al., 2024). Despite initiatives since 2007, Malaysia's BIM adoption remains low due to high costs, immature implementation, and limited policy support (CIDB Malaysia, 2021; Zaini et al., 2020; Memon et al., 2014). Adoption willingness and investment have declined since 2016, worsened by external factors like COVID-19 and rising costs (CIDB Malaysia, 2021; Zahrizan et al., 2013).

The aim of this research is to investigate the role of BIM in advancing sustainability and achieving ESG goals within the construction industry. It identifies factors influencing BIM adoption, such as technical challenges, strategic changes, risks, costs, cultural barriers, and legal issues. By comparing BIM adoption strategies in Malaysia with countries like the US, UK, Hong Kong, China, and Singapore, the study seeks to

develop effective approaches to overcome barriers and enhance BIM implementation for sustainable construction.

In order to fulfil the aim of this research there are three objectives as follows:

1. To investigate benefits of BIM in supporting sustainability construction to achieve ESG goals in contractor firms.
2. To examine the barriers that influence BIM implementation in achieving ESG goals in contractor firms.
3. To analyse the different strategies and its effectiveness in the adoption of BIM to achieve ESG goals in contractor firms.

This paper reviews literature on BIM adoption barriers and strategies from contractors' perspectives, focusing on technical, strategic, financial, cultural, and legal factors affecting ESG goals (CIDB Malaysia, 2021; Wong et al., 2010; Gibbs et al., 2015). It compares Malaysia's BIM adoption with countries like the US, UK, Hong Kong, China, and Singapore. A quantitative survey will be conducted among Johor contractors to assess BIM adoption levels, key barriers, and strategies to support sustainable construction (Wong et al., 2010). The results aim to guide BIM implementation frameworks and support future research.

II. LITERATURE REVIEW

Sustainable building focuses on managing energy use and carbon emissions throughout a building's lifecycle to support global sustainability goals (Oh et al., 2018). It aims to balance environmental protection, economic justice, and social responsibility, integrating these principles into all stages of the built environment (Prizeman et al., 2020; Pan et al., 2018). BIM supports this by enhancing building performance and sustainability through lifecycle integration from material extraction to disposal or reuse (Buyle et al., 2013; Gustavsson et al., 2010; Kotaji et al., 2003). As a socio-technical system, BIM combines 3D modelling and data management with broader institutional and societal factors (Wong & Zhou, 2015).

ESG investing is a socially conscious investment strategy that promotes sustainable development and long-term growth for the benefit of the community by investing shareholders' funds in businesses that focus on social, environmental and governance principles. According to (Gupta et al., 2021), the three pillars of the ESG framework are environmental, social and governance factors. Responsible investment is defined as a strategy to incorporate ESG factors into investment decisions and ownership practices, which is at the heart of the (PRI, 2021) framework.

Table 1.0 ESG international framework (EBA, 2021)

Dimension	Descriptions
Environmental (E)	Focuses on sustainability and ecological impact, including GHG emissions, energy efficiency, waste management, biodiversity, and eco-friendly innovation.
Social (S)	Covers workforce rights, labor conditions, health and safety, diversity, poverty impact, supply chain management, and community well-being.
Governance (G)	Involves corporate integrity, accountability, transparency, executive pay, board diversity, anti-corruption measures, and shareholder rights.

ESG factors are crucial in assessing corporate behavior and financial performance, supporting decision-making and investment appraisal. These factors help balance economic growth with sustainable development and are heavily weighted in the ESG concept. ESG is an integrated approach to governance, aiming to create long-term value.

BIM is a digital process that integrates traditional construction methods by creating, analyzing, and managing digital project models (CIDB Malaysia, 2012; Eastman et al., 2011). The 5D BIM system enhances project management by combining 3D modeling, 4D scheduling, and 5D cost estimation, enabling comprehensive project visualization and proactive decision-making (Forgues et al., 2012; Liu et al., 2014; Fischer et al., 2004; Kunz & Fischer, 2020). BIM supports energy-efficient design, lifecycle energy assessment, and improved project efficiency, reducing costs and waste (Eastman et al., 2011).

The multi-dimensional BIM approach enhances project coordination, sustainability, and performance (Eastman et al., 2011; Kunz & Fischer, 2020). 3D BIM is increasingly adopted in large-scale projects (e.g., Forest City) for optimized site layout, clash detection, and error reduction (Rui et al., 2021; Qi et al., 2018). 4D BIM improves construction efficiency through progress tracking, schedule optimization, and dynamic adjustments to mitigate delays (Tran et al., 2021). Meanwhile, 5D BIM streamlines cost control by automating quantity take-offs and minimizing manual verification (Amoruso et al., 2018). Given these advantages, this study focuses on 3D, 4D, and 5D BIM for sustainable construction aligned with ESG goals.

Table 2.0 Explanation of 3D, 4D and 5D BIM (Abbasnejad and Moud, 2013)

BIM	Explanation
3D Shared Information Model	3D BIM enhances project visualization, clash detection, virtual mock-ups, and prefabrication, allowing early problem identification and improved efficiency.
4D Construction Sequence	4D BIM supports construction planning by visualizing site logistics, schedules, and safety measures, aiding real-time decision-making.
5D Estimating & Costing	5D BIM improves cost estimation and value engineering by providing real-time material and cost data, though expert pricing is still required.

BIM plays a vital role in sustainable construction by optimizing resource use, reducing energy consumption, and managing carbon emissions (Deng et al., 2021). Sustainable building focuses on minimizing ecological footprints, improving energy efficiency, and promoting healthier environments (Markopoulos et al., 2024). BIM enhances sustainability by providing workflow data and managing energy usage throughout construction operations (Najjar et al., 2017). Table 3.0 outlines the capabilities of 3D, 4D, and 5D BIM in sustainable constructions.

Table 3.0 Capabilities of 3D, 4D and 5D BIM

BIM	Capabilities	References
3D	Model walkthroughs	(Rui et al., 2021)
	Clash detection work	(Xiao et al., 2019; Ma et al., 2019; Abobakirov, 2023)
	Project visualization	(Umar et al., 2015)
	Virtual meetings	(Abbasnejad & Moud, 2013; Abobakirov, 2023)
4D	Visualization of time and space relationships of construction activities	(Muxwiuwe, 2011; Sattineni & Macdonald, 2014; Rui et al., 2021; Umar et al., 2015; Gledson & Greenwood, 2016; Buchuum-Slorup & Andersson, 2010; Heesom & Mahdjoubi, 2002; Jupp, 2017; Ahmadi & Arashpour, 2020; Abobakirov, 2023)
	Optimization of construction processes	(Sattineni & Macdonald, 2014; Umar et al., 2015; Jupp, 2017; Cheng et al., 2015; Abobakirov, 2023)
	Clash detection and enhanced team coordination	(Umar et al., 2015; Dawood & Sikka, 2009; Abobakirov, 2023)
	Construction schedule analysis and resource management	(Rui et al., 2021; Umar et al., 2015; Gledson & Greenwood, 2016; Koo & Fischer, 2000; Jupp, 2017; Cheng et al., 2015; Ahmadi & Arashpour, 2020; Abobakirov, 2023; Candelario-Garrido et al., 2017)
	Reduction of errors and enhanced communication	(Umar et al., 2015; Gledson & Greenwood, 2016; Dawood & Sikka, 2009; Ahmadi & Arashpour, 2020; Abobakirov, 2023)
	Construction safety, waste, and risk management	(Cheng et al., 2015; Jupp, 2017; Jin et al., 2018; Jin et al., 2019)
5D	Cost estimation and project budget management	(Sattineni & Macdonald, 2014; Rui et al., 2021)
	Effective quantity take-off and reduction of change orders	(Rui et al., 2021; Hasan & Rasheed, 2019; Eastman, 2011; Abu-Hamd et al., 2016)

BIM technology enhances construction efficiency by integrating data, improving design accuracy, and reducing errors (Wang et al., 2019). It facilitates model-based visualization, supporting risk management and clash detection (Zou et al., 2019). 4D BIM incorporates time elements, while 5D BIM integrates cost and progress tracking, enabling dynamic project analysis (Rui et al., 2021; Abid et al., 2020; Shaqour, 2022). Additionally, BIM optimizes cost management for quantity surveyors by providing accurate material quantities and streamlining contract and quality control (Rui et al., 2021). According to (Abobakirov, 2023), BIM supports energy analysis, life cycle assessments, and environmental impact evaluations. It enhances energy efficiency, facility management, and material selection for sustainable construction

Integrating ESG standards with BIM enhances resource efficiency, reduces waste, and ensures compliance with sustainability norms in the construction industry (Markopoulos et al., 2024; Azhar, 2011; Volk et al., 2014). BIM optimizes building design through energy simulations, promoting renewable energy adoption and environmental sustainability (Matarneh et al., 2019; Kibert, 2016). Additionally, it improves safety management by modeling construction sequences and predicting hazards while fostering transparency through a shared digital platform for better communication and decision-making (Jalaei & Jrade, 2015).

Table 4.0 BIM benefits related to ESG

Dimension	BIM Benefits Related to ESG	References
Environmental	Minimization of Resource Waste	(Umar et al., 2015)
	Sustainable Material Selection	(Martins et al., 2022)
	Reduction of Construction Material Usage	(Najjar, Figueiredo, & Evangelista, 2019)
	Waste Management	(Cheng et al., 2015; Ahmadi & Arashpour, 2020)
	Carbon Footprint Management	(Chhatwani & Golparvar-Fard, 2016)
Social	Health and Safety Management	(Martins et al., 2022; Zhang et al., 2022)
	Proactive Hazard Detection	(Zhang et al., 2022)
	Decision-Making and Communication Tool	(Ahmadi & Arashpour, 2020; Shou et al., 2015)
	Construction Risk Mitigation	(Jin et al., 2018; Jin et al., 2019)
Governance	Improved Decision-Making	(Sloot et al., 2019)
	Interdisciplinary Coordination	
	Real-Time Collaboration	
	Accurate Scheduling and Resource Management	
	Design and Process Optimization	
	Team Collaboration and Education	(Crowther & Ajayi, 2021)

Although BIM can greatly improve sustainable construction and achieve ESG goals, contractors can encounter barriers to adopting BIM. Common barriers include technical issues, strategic changes, risk concerns, high costs and time investment, cultural resistance, and legal constraints. These factors impact contractors' willingness to adopt BIM. **Table 5.0** outlines these barriers.

Table 5.0 Explanations of common barriers of BIM adoption to contractors

Barriers	References
Cost and Time (Including Training)	(Sattineni & Macdonald, 2014; Ahmadi & Arashpour, 2020; Tan et al., 2019)
Cultural Barriers and Resistance to Change	(Hasan & Rasheed, 2019; Eastman et al., 2011; Arayici et al., 2009, 2011; Kullvén & Nyberg, 2014; Tan et al., 2019; Swallow & Zulu, 2019)
Legal and Ownership Issues	(Ahmadi & Arashpour, 2020; Tan et al., 2019)
Collaboration and Risk Management	(Azhar, 2011; Tan et al., 2019; Eastman et al., 2011)
Technical and Software Limitations	(Sattineni & Macdonald, 2014; Kullvén & Nyberg, 2014; Hasan & Rasheed, 2019; Tan et al., 2019)
Unclear Economic Benefits	(Tan et al., 2019)
Risk of New and Uninsurable Liabilities	

Malaysia faces significant BIM adoption barriers, primarily high implementation costs (software, training, hardware) and limited expertise, as consistently reported by CIDB (2016, 2019, 2021). The transition from CAD demands substantial investments (Ahmadi & Arashpour, 2020; Hong et al., 2020), compounded by skilled labor shortages (Swallow & Zulu, 2019; Kullvén & Nyberg, 2014). Recent CIDB (2021) findings identified six additional challenges: lack of management support (ranked 5th), complex BIM roles, low market demand, poor data management, unsuitable projects, and interoperability issues (Xu et al., 2014). These context-specific hurdles underscore the need for tailored strategies, particularly when compared to high-adoption nations (US, UK, China, Singapore, Hong Kong) (CIDB Malaysia, 2021).

BIM adoption rates indicate industry uptake, with higher levels in the US, UK, Hong Kong, and Singapore (71–80%), and moderate rates in China (67%) and Malaysia (55%) (CIDB BIM Report 2021; Jiang et al., 2022; NBS; Construction Industry Council). While BIM is growing globally, Malaysia still lags behind leading countries. Adoption strategies differ across nations, involving education, mandates, funding, and regulation, contributing to varying adoption levels.

Table 6.0 Comparison of different countries' strategies

Strategies	Countries					
	UK Source: Jiang et al. (2022)	US Source: Jiang et al. (2022)	Hong Kong Source: Wong et al. (2011)	China Source: Zhou et al. (2019)	Singapore Source: Jiang et al. (2022)	Malaysia Sources: CIDB Malaysia (2015); CIDB Malaysia (2021);JKR (2021); Malay Mail (2020); Lai and Gimino (2024)
Education (Training/ Courses)	- 2016: BIM academic forum launched. - 2017: E-learning module introduced for all levels. - 2017 onward: Continued focus on research.	2006-2016: USACE training, NIBS online course, MIT BIM standards introduced.	HKIBIM (2009): Promotes BIM education and awareness, linking universities and government bodies for training.	- Universities and organizations focus on BIM skills and training. - China Construction Education Association issued BIM skills assessment plan (2015).	- 2011–2016: Provided training, outreach programs, and specialist diplomas. - 2016 onwards: Launched new training programs at all levels.	2015: BIM Training Centre and BIM Education Syllabus introduced.
Regulation Standards/Guidelines	- 2011-2016: PAS, BS, and ISO standards introduced and updated. - 2017 onward: Global collaboration with new ISO and Gemini Principles.	2005-2018: Multiple BIM guides and standards introduced, including National BIM and state-specific guidelines	- CSWP Standard: Updates CAD standards (AutoCAD, MicroStation) to support BIM. - Housing Authority (2009): Adopts BIM for sustainable design and efficiency in public housing.	- MOHURD issued BIM guides (2007) and developed five national BIM standards (2015). - Policies for A-level construction firms to master BIM by 2020.	- 2010–2015: Introduced BIM e-submission guidelines, Singapore BIM Guides (V1.0, V2.0), and BIM Essential Guides. - 2016 onwards: Expanded guidelines to include DfMA, VDC, and Asset Information Delivery.	- 2016: Malaysia CIDB BIM Guidelines established. - 2021: JKR BIM Guidelines established.
Cost/ Fundings	2017 onward: BIM Research Funding introduced to support innovation.	No significant funding actions noted.	Implied government support through public project backing.	Government investment in BIM R&D and academic projects.	- 2010–2018: Continuous funding through the BIM fund. - 2016 onwards: Focused on R&D funding.	- Implied government support through the creation of BIM centres and projects. - 2020: SME Technology Transformation Fund (STTF) was launched for SME to adopt digitalisation and automation.
Demonstration	- 2011: BIM forum and awards for SMEs. - 2015-2016: BIM Toolkit for deliverables introduced. - 2017 onward: BIM case library and international collaboration.	2006-2010: USACE and BIM forum used for showcasing BIM success stories.	- Housing Authority: Pilots BIM in modular flats and public housing projects. - Hong Kong BIM Programme: Proposes pilot projects to test BIM adoption.	Programs during the 12th Five-Year Plan (2011-2015) promoted BIM in real projects.	- 2010-2012: Piloted BIM projects. - 2011 onwards: Promoted success stories and held forums	2014: Promotion and awareness through the National BIM Pilot Project.
BIM Mandates	- 2011: Mandated 3D BIM for public projects by 2016. - 2016 onward: BIM Level 2 mandated for public and private sectors.	2009-2018: BIM mandated for large construction projects by VA, Wisconsin, Indiana, and LACCD.	- CSWP Working Group (2007): Sets timeline for BIM use in public projects. - Hong Kong BIM Programme: Proposes mandatory BIM for all new government projects.	MOHURD's stepwise implementation, starting with large enterprises, with a 2020 mastery target for key firms.	- 2011–2012: BIM e-submission became mandatory for public sector projects. - 2013–2015: Expanded mandates to include large-scale projects (over 20,000 m^2, then 5,000 m^2).	- 2017: Mandatory BIM submission for architecture. - 2018: Mandatory BIM submission for engineering. - 2018: Mandatory BIM for public project cost over RM100 million. - 2019-2020: Full BIM lifecycle and advanced BIM technology adoption. - 2024: Mandatory BIM for public and private project cost over RM10 million.
Initiators and Drivers	- 2011-2012: BIM Task Groups and BIM Regions formed. - 2016: UK BIM Alliance and Public Sector BIM Working Group established. - 2017 onward: Led by the Center for Digital Built Britain.	2003-2008: National 3D-4D BIM Program, BIM Standard Committee, and buildingSMART established.	- DevB: Leads BIM implementation for public infrastructure. - HKIBIM: Sets BIM standards and provides education. - GPA/ArchSD: Use BIM for government space and property management.	- MOHURD and China BIM Development Union lead initiatives. - China Construction Education Association supports BIM education.	- 2010: CCIT initiated the first BIM roadmap. - 2011: Established the BIM Steering Committee. - 2015: Launched the second BIM roadmap focusing on advanced BIM and R&D.	2014: CIDB BIM Centre and National BIM Pilot Project launched.

Malaysia has progressed in BIM adoption through education (since 2015), legal standards (2016), and targeted funding like the National BIM Pilot Programme. However, compared to global leaders (e.g., UK, China, Singapore), its e-learning, regulations, and R&D funding remain less developed. While Malaysia mandated BIM for engineering (2017) and architecture (2018), other nations enforce broader requirements. Initiatives like CIDB BIM Centre drive adoption, but expanded training, funding, and cross-industry collaboration could accelerate progress (CIDB Malaysia, 2016; National BIM Report, 2022).

III. METHODOLOGY

Methodology used in this study was similar to the research of (Hasan & Rasheed, 2019; Manzoor et al., 2021; and Al-Ashmori et al., 2020). As shown in Figure 1.0, this research comprises four phases in order to achieve the aim and objectives.

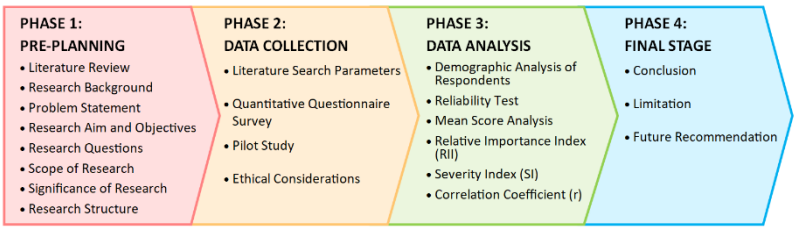


Figure 1.0 Research design flow chart

This study investigates BIM implementation in sustainable construction to achieve ESG goals through a comprehensive mixed-methods approach. The research begins with a systematic literature review using keywords such as "BIM," "ESG," and "sustainable construction" across major academic databases. A quantitative survey targets 191 G7 contractors in Johor, selected from 380 using Krejcie & Morgan's 1970 sampling table to address regional research gaps identified in previous studies (Yunus et al., 2023; Al-Ashmori et al., 2020, 2021). The questionnaire, validated through a pilot study with five quantity surveyors, collects data on respondent background, company background, benefits, barriers, and strategies for BIM adoption using Likert-scale. Data analysis employs SPSS for reliability testing (Cronbach's alpha), mean score analysis, Relative Importance Index (RII) for ranking benefits and strategies, Severity Index (SI) assessment of barriers, and correlation analysis between barriers and strategies, following established methodological frameworks (Connolly, 2007; Pallant, 2007; Al-Ashmori et al., 2022). This approach combines rigorous literature synthesis with empirical data collection to develop actionable insights for BIM adoption in Malaysia's sustainable construction sector.

IV. FINDINGS AND ANALYSIS

This section presents and analyzes survey results from G7 contractors in Johor, focusing on three objectives: identifying BIM's ESG benefits, examining adoption barriers, and assessing enhancement strategies. The findings reveal industry practices and challenges, linking them to existing literature to uncover key trends and implications for sustainable construction.

Table 7.0 Ranking of benefits of BIM adoption by construction companies

	Benefits of BIM Adoption in Construction Company	RII	Mean	SD	Ranks
a1	Optimizes site layout during pre-construction based on real conditions	0.767	3.833	0.786	4
a2	Enhances conflict detection, improving quality control and advancing construction	0.822	4.111	0.758	1
a3	Improves stakeholder understanding, communication, and reduces design misconceptions	0.744	3.722	1.166	6
a4	Enables immersive 3D or AR presentations, enhancing stakeholder engagement and decision-making	0.756	3.778	0.732	5
a5	Simulates construction sequences to resolve planning issues and prevent rework	0.778	3.889	0.707	3
a6	Streamlines processes, reduces rework, and enhances on-site resource flow	0.733	3.667	0.840	7
a7	Identifies physical conflicts and improves design team coordination and information flow	0.700	3.500	0.857	10
a8	Enables precise scheduling, task dependencies, and effective resource utilization	0.678	3.389	0.608	12
a9	Reduces mistakes by validating building plans and improving team collaboration	0.711	3.556	0.705	9
a10	Aids in managing waste, mitigating site risks, and allocating safety resources	0.689	3.444	0.705	11
a11	Provides quick access to project costs, enhancing budget control and transparency	0.800	4.000	0.686	2
a12	Automates cost estimation, reduces change orders, and increases accuracy	0.722	3.611	0.778	8

Contractors view BIM as a key enabler of sustainable construction aligned with ESG goals. Top-rated benefits include improved stakeholder collaboration, real-time activity monitoring, and project risk reduction each supporting governance, environmental, and social aspects of ESG, respectively. These align with previous research showing BIM's role in reducing rework, optimizing resources, and improving coordination (Eastman et al., 2011; Umar et al., 2015). While adoption remains low, strong awareness of BIM's value highlights potential for wider uptake through focused education and strategic implementation.

Table 8.0 Ranking of barriers of BIM adoption by construction companies

	Barriers of BIM Adoption in Construction Company	SI	SD	Ranks
b1	High cost of software	76.67	1.043	6
b2	High training cost	68.89	0.992	13
b3	High cost of technology	77.78	0.900	5
b4	Lack of BIM knowledge	67.78	0.698	14
b5	Lack of top management support	61.11	0.802	20
b6	Lack of experience in coordinating the construction documents by using BIM	74.44	0.752	8
b7	Lack of time for experimentation and adoption in a fast-paced project	81.11	0.873	3
b8	No established contractual framework for working with BIM	65.56	0.895	16
b9	Lack of organization familiarization with adopting BIM	71.11	0.922	11
b10	Insufficient BIM training available	62.22	0.963	19
b11	Reluctance to initiate new workflows for adoption of BIM	66.67	0.907	15
b12	Lack of references/sources to assist in adopting BIM	63.33	0.924	18
b13	Lack of direction of BIM in the industry	72.22	0.778	10
b14	Lack of awareness of BIM benefits	70.00	1.043	12
b15	The complexity of the new roles in BIM-based construction projects	73.33	0.840	9
b16	Lack of BIM demand	64.44	1.060	17
b17	Difficulty in adopting BIM coordination	91.11	0.616	1
b18	Lack of clear policies that support BIM adoption	78.89	0.639	4
b19	Inadequate information management processes for BIM	75.56	0.548	7
b20	Lack of appropriate projects to adopt BIM	86.67	0.767	2

Key barriers to BIM adoption include coordination difficulties, lack of suitable projects, limited time for training, and high initial costs for software, hardware, and personnel—echoing Memon et al. (2014). Even large firms have not fully implemented BIM, indicating that external factors like the absence of national guidelines, standardized workflows, and policy mandates are bigger hurdles than internal capability. Cultural

resistance and workflow complexity also hinder uptake. These findings align with CIDB Malaysia (2021), highlighting the urgent need for coordinated policies and industry support to drive BIM adoption for ESG-aligned construction.

Table 9.0 Ranking of strategies to enhance BIM adoption in construction companies

	Strategies to Enhance BIM Adoption in Construction Company	RII	Mean	SD	Ranks
c1	Create BIM institutes for training young or fresh graduates	0.800	4.000	0.686	4
c2	Provide financial aid to reduce the cost of adopting BIM	0.822	4.111	0.900	2
c3	Develop BIM adoption guidelines	0.811	4.056	0.725	3
c4	Develop programs to integrate BIM into education curricula and academia	0.711	3.556	0.705	12
c5	Develop programs to increase BIM awareness and understanding	0.789	3.944	0.725	5
c6	Foster market demand for BIM	0.722	3.611	0.698	11
c7	Develop a digital transformation strategy for BIM	0.778	3.889	0.676	6
c8	Develop BIM standards	0.833	4.167	0.786	1
c9	Develop BIM-related contractual frameworks	0.767	3.833	0.707	7
c10	Initiate pilot projects to exploit evidence-based benefits of adopting BIM	0.744	3.722	0.669	9
c11	Mandate BIM adoption in the construction industry	0.733	3.667	0.767	10
c12	Develop programs for improving BIM competencies	0.756	3.778	0.732	8

The most effective strategies for BIM adoption identified were: (1) developing national BIM standards, (2) providing government financial support, and (3) initiating pilot projects. Standardized guidelines are seen as critical for consistent implementation, addressing the fragmentation noted by (Zahrizan et al., 2013). Financial support helps offset high initial costs, especially for SMEs (Memon et al., 2014). Pilot projects offer a low-risk way for contractors to build confidence and technical skills, aligning with successful practices in the UK and Singapore (CIDB Malaysia, 2021).

Correlation coefficient analysis also revealed strong positive correlations between the most significant barriers and the recommended strategies. For example, the barrier of high training costs correlated closely with the strategy of financial support, while the lack of workflow clarity correlated with the need for national standards. This suggests that the strategies are not only theoretically sound but also practically responsive to the contractors' real challenges.

Table 10.0 Relationship between barriers and strategies with correlation value 0.600 and above

Barriers	Strategies	Correlation (r-value)
The complexity of new roles in BIM-based construction projects (b15)	• Develop BIM-related contractual frameworks (c9)	**0.832**
	• Develop a digital transformation strategy for BIM (c7)	**0.693**
	• Develop BIM standards (c8)	**0.666**
Lack of time for experimentation and adoption in a fast-paced project (b7)	• Initiate pilot projects to exploit evidence-based benefits of adopting BIM (c10)	**0.810**
	• Mandate BIM adoption in the construction industry (c11)	**0.779**
Inadequate information management processes for BIM (b19)	• Develop BIM-related contractual frameworks (c9)	**0.667**
	• Develop BIM standards (c8)	**0.667**
High cost of technology (b3)	• Develop BIM-related contractual frameworks (c9)	**0.667**
	• Develop programs for improving BIM competencies (c12)	**0.621**
High training cost (b2)	• Provide financial aid to reduce the cost of adopting BIM (c2)	**0.628**

Conversely, strategies such as promoting BIM through branding, CSR activities, or public awards were rated as less effective. These were viewed as secondary to direct, structural, and policy-driven measures. This implies that for BIM to support ESG goals meaningfully, the focus should be on reducing technical and financial barriers, not merely on image or awareness campaigns.

Overall, the analysis demonstrates that contractors favour actionable, policy-oriented strategies that provide clear guidance and tangible support. These findings offer a practical foundation for future initiatives and policy development aimed at accelerating BIM adoption in Malaysia's construction industry in alignment with sustainability and ESG objectives.

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ASSESSING EMERGENCY PREPAREDNESS IN NURSING HOMES

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ABSTRACT

This research paper assesses the emergency preparedness of nursing homes, drawing from an extensive literature review to examine existing policies, practices, and response strategies. Given the high vulnerability of the elderly population in these facilities, ensuring robust emergency preparedness is essential for minimizing risks during crises such as natural disasters, health emergencies, or other critical incidents. The literature review provides a comprehensive analysis of current frameworks, identifying key challenges and gaps in training, resource allocation, and communication. In addition, a mixed-methods approach was employed to evaluate the preparedness of nursing homes through staff surveys, emergency plan reviews, and an examination of past emergency events. The findings underscore significant areas for improvement and offer evidence-based recommendations for enhancing preparedness, including regular staff training, better resource management, and more effective communication strategies. This study contributes valuable insights for policymakers, nursing home administrators, and healthcare professionals working to strengthen emergency preparedness in long-term care facilities.

Keywords: Communication Strategies, Emergency Preparedness, Nursing Homes, Resource Allocation, Staff Training

I. INTRODUCTION

A 2023 study published in the Archives of Public Health defines emergency preparedness as the capability to manage emergencies and effectively respond to shocks, emphasizing the critical role of appropriate actions during crises (Khatri, 2023). It involves creating sustainable infrastructure, shelters, and evacuation plans that serve both immediate and long-term needs in emergencies (Goniewicz, 2023)

Public nursing homes adhere to the Private Healthcare Facilities and Services Act 1998 (Act 586) and the Care Centres Act 1993 (Act 506). However, private nursing homes often face significant challenges related to infrastructure and safety, raising critical concerns about the well-being of elderly residents, particularly given their heightened vulnerabilities.

A. Problems And Issues

In Malaysia, it is worth noting that many private nursing homes operate in repurposed residential buildings that fail to meet appropriate design standards for elderly care. For instance, in 2024, the Health Ministry reported that 1,028 nursing homes were uncertified, raising serious concerns about the safety and suitability of these facilities for elderly residents (Zahiid, 2024), while public nursing homes comply with the Private Healthcare Facilities and Services Act 1998 (Act 586) and the Care Centres Act 1993 (Act 506), these regulations do not fully address the specific requirements of nursing homes. Specifically, issues such as emergency evacuation plans, staff training, and effective coordination with local services remain insufficiently covered. Therefore, it becomes evident that tailored emergency preparedness plans are critically needed to address these gaps and ensure the well-being of residents (Goniewicz, 2023)

II. LITERATURE REVIEW

A. Emergency Preparedness in Nursing Homes

Emergency preparedness in nursing homes plays a critical role in safeguarding the safety and well-being of elderly residents during times of crisis. Nevertheless, it is important to note that, despite the increasing dependence on nursing homes for elder care, many facilities continue to face significant challenges. Therefore, by analysing these challenges, this section seeks to identify the areas that demand urgent attention to enhance the overall preparedness and resilience of nursing homes in handling emergencies effectively. Ultimately, addressing these shortcomings is vital to ensuring the protection and security of the vulnerable elderly population residing in such facilities.

2.1 Lack of Training and Emergency Drills

It is well-established that many nursing homes lack the practice of conducting regular emergency drills and fail to provide adequate training for staff. For example, training programs must be mandated to ensure preparedness in critical situations (MARI, 2023). Furthermore, the effectiveness of emergency evacuation plans relies heavily on well-trained personnel who are capable of assisting elderly residents during evacuations. Unfortunately, challenges such as limited staffing and high employee turnover in Malaysian nursing homes often lead to insufficient preparedness during emergencies. In addition, the inconsistency in training programs and the lack of resources for staff remain significant obstacles to improving emergency preparedness in these facilities (Chelvi, 2022)

2.2 Deficiencies in Infrastructure and Building Design

Most private nursing homes in Malaysia operate in repurposed residential buildings that are not designed to meet elder care needs, highlighting the importance of prioritizing structural modifications such as fire exits, handrails, and non-slip flooring to enhance safety (Noor, 2019). Furthermore, elderly care centers must cater to both daily living and medical needs by incorporating elder-friendly designs such as lower counter heights, non-slip flooring, handrails, and communal spaces for social interaction (Du, 2024). It is also emphasized that the importance of providing long-term comfort through features like personalized rooms, outdoor access, and spaces for daily activities, which are often absent from current facilities. (Noor, 2019) However, the lack of these standards has led to dire consequences, such as the tragic 2024 fire at the Persatuan Keluarga Putih elderly care center, which resulted in six fatalities and 55 injuries. Despite passing recent fire prevention inspections, the facility was found to lack proper evacuation plans, adequately trained staff, and sufficient infrastructure to handle emergencies effectively (Izwan, 2024). This underscores the urgent need for comprehensive improvements in the structural and operational standards of nursing homes to ensure the safety and well-being of their residents.

2.3 Insufficient Regulatory Enforcement

Although regulations are in place, it is evident that their enforcement remains inadequate, allowing many nursing homes to operate without adhering to established emergency preparedness guidelines, which places residents at risk (Goniewicz, 2023). Moreover, emergency evacuation preparedness in Malaysian private nursing homes is poorly regulated, with numerous facilities failing to comply with necessary safety standards. To address this, stricter regulatory enforcement and regular audits are essential for ensuring these facilities are adequately prepared to handle emergencies effectively (Ismail, 2020). For example, in 2017, a tragic fire at an elderly care centre resulted in the deaths of five residents, with investigations revealing that the facility lacked a proper permit and was owned by a foreign national, highlighting major concerns about inadequate regulation and oversight within Malaysia's private care sector (Ak, 2017). Similarly, a fire at a nursing home in Petaling Jaya exposed significant safety lapses, including inadequate emergency preparedness and insufficient fire safety measures (Zainal, 2023). These incidents emphasize the urgent need for improved regulatory frameworks, stricter inspections, and robust enforcement to better protect the vulnerable elderly population residing in nursing homes.

2.4 Limited Financial Resources

It is evident that many nursing homes lack the financial resources required to invest in essential safety measures. Consequently, government subsidies or incentives should be introduced to support private nursing homes in upgrading their facilities to comply with emergency preparedness standards (Du, 2024). Furthermore, as highlighted by Krishnan and Rani (2024) there is a pressing need for improved regulatory oversight, enhanced funding, and comprehensive infrastructure upgrades. These measures are crucial to ensuring that

nursing homes provide safe and adequate care for their residents, particularly given the vulnerabilities of the elderly population.

1.5 Inadequate Coordination with Emergency Services

According to the Office of Inspector General (2023), it is important to highlight that a lack of collaboration between nursing homes and local emergency services, such as fire departments and medical responders, often leads to delayed response times during crises. For this reason, establishing direct communication channels and conducting regular inspections are vital steps to enhance emergency preparedness. Furthermore, as emphasized by the Joint Commission (2024), structured emergency management is crucial, yet many Malaysian facilities fail to implement such measures. For instance, inadequate coordination with emergency services frequently results in delays during critical situations, further compromising the safety of residents.

III. RESEARCH METHODOLOGY

The research methodology is primarily grounded in a comprehensive literature review. Specifically, the search for documentation and discussion entails an extensive analysis of the current state of emergency preparedness in nursing homes situated in Kinta, Perak. Notably, the information utilized in this study is derived from secondary data sources, including relevant books, scholarly journals, official reports, web pages, and conference proceedings. Furthermore, the study aims to identify and examine the critical factors that contribute to challenges in implementing effective emergency preparedness measures in these facilities. By leveraging this approach, the research seeks to provide valuable insights into areas requiring improvement to enhance the overall safety and readiness of nursing homes.

IV. DISCUSSION AND FINDINGS

The critical factors of emergency preparedness in nursing homes, particularly in Malaysia, need to be addressed consistently. An extensive literature review has been conducted, identifying key challenges and factors affecting the implementation of effective emergency preparedness measures.

Based on Table 1, there are six (5) numbers of critical factors found in the literature review. In detail, the scholars are identified as A (Mari, 2023); B (Chelvi, 2022); C (Noor, 2019); D (Du, 2024); E (Izwan, 2024) ; F (Goniewicz, 2023); G (Ismail,2020); H (Ak,2017); I (Zainal, 2023); J (Krishnan and Rani, 2024); K (Office of Inspector General, 2023) and L (The Joint Commission, 2024). The discussion of three (3) high numbers of critical factors has been done as follows:

Table 1.0 Critical Factors for Emergency Preparedness in Nursing Homes

No	Critical Factors	A	B	C	D	E	F	G	H	I	J	K	L	Total
1	Staff Training and Emergency Drills	✔	✔			✔								3
2	Inappropriate Building Design and Insufficient Equipment			✔	✔	✔					✔			4
3	Inadequate enforcement of rules and standards						✔	✔	✔	✔	✔			5
4	Limited Financial Resources				✔						✔			2
5	Insufficient Collaboration with Emergency Services											✔	✔	2

4.1 Lack of Staff Training and Emergency Drills

According to Mari (2023), Chelvi (2022), and Izwan (2024), it is undeniable that emergency preparedness depends heavily on well-trained staff capable of assisting elderly residents during crises. However, many nursing homes in Malaysia fail to conduct regular emergency drills or provide sufficient training for their staff, leading to unpreparedness during critical situations (Mari, 2023). Moreover, the effectiveness of evacuation plans is greatly influenced by the presence of competent staff, yet challenges such as limited manpower and high employee turnover continue to exacerbate these issues (Chelvi, 2022). For instance, the tragic fire at the Persatuan Keluarga Putih elderly care centre in 2024 underscored the severe consequences of inadequate staff training and the absence of proper emergency drills, even though the facility had passed fire prevention inspections (Izwan, 2024). These incidents highlight the urgent need for improved training programs and consistent emergency drills to ensure the safety of elderly residents in nursing homes.

4.2 Inappropriate Building Design and Insufficient Equipment

According to Noor (2019), Du (2024), Izwan (2024), and Krishnan and Rani (2024) it is crucial to acknowledge that many private nursing homes operate in converted residential buildings that lack essential elder-friendly features such as fire exits, handrails, and non-slip flooring, all of which are vital for ensuring safety (Noor, 2019). Furthermore, both Du (2024) and Noor (2019) highlight the importance of incorporating additional features such as personalized rooms, outdoor access, and communal spaces to promote long-term comfort and facilitate social interaction for elderly residents' amenities that are often missing in current facilities. Moreover, one of the contributing factors to the 2024 fire incident in a nursing home was the absence of well-developed evacuation plans and inadequate infrastructure to support emergency responses (Izwan, 2024). Krishnan and Rani (2024) also emphasized the importance of nursing homes implementing thorough infrastructure improvements to enhance their facilities and services. This emphasizes the urgent need for proper designs and enhancements in nursing homes to cater to the unique requirements of elderly care.

4.3 Insufficient Regulatory Enforcement

According to Goniewicz (2023), Ismail (2020), Ak (2017), Zainal (2023), and Krishnan and Rani (2024) it is evident that the enforcement of emergency preparedness regulations in Malaysian nursing homes is lack of strict oversight, thereby posing significant safety risks to residents. Many facilities fail to meet the required standards due to insufficient inspections and a lack of accountability (Goniewicz, 2023) Hence, regular audits and stricter penalties are essential to ensure compliance (Ismail, 2020). For instance, in 2017, a tragic fire at an unlicensed elderly care center claimed five lives, revealing the absence of a proper permit and critical regulatory oversight (Ak, 2017). Similarly, a fire in Petaling Jaya exposed serious deficiencies in emergency preparedness and fire safety measures (Zainal, 2023). Furthermore, Krishnan and Rani (2024) underscored the pressing need for improved regulatory oversight to guarantee safe and adequate care in nursing homes. In addition, establishing direct communication channels and increasing the frequency of inspections have been highlighted as vital measures to enhance emergency preparedness. This emphasizes the urgency of addressing these regulatory gaps to safeguard the well-being of elderly residents.

ACKNOWLEDGEMENT

The Author wishes to extend sincere thanks to the Building Surveying Department of Universiti Teknologi MARA, Perak branch, particularly to the supervisor for their support in making this publication possible.

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EXPLORING KEY FACTORS OF INDOOR ENVIRONMENTAL QUALITY AFFECTING OCCUPANCY AND COMFORT CONDITION IN ACADEMIC LIBRARY: A REVIEW

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ABSTRACT

Libraries are among the most frequented spaces by students, particularly during exam periods, making the quality of the indoor environment crucial for user comfort, well-being, and productivity. Indoor Environmental Quality (IEQ) significantly influences the creation of conducive study environments while also preserving library materials. However, maintaining optimal IEQ remains challenging due to the high energy consumption of HVAC systems and the need to manage thermal comfort, acoustics, and lighting effectively. This study aims to examine the key components of IEQ in libraries and assess their impact on library users. Specifically, it focuses on factors such as indoor air quality, thermal comfort, acoustic quality, and lighting, all of which contribute to occupant satisfaction and comfort. A systematic review was employed to gather and analyze relevant studies on the subject. The findings highlight that indoor air quality, temperature regulation, noise levels, and lighting conditions significantly influence the comfort and performance of library occupant. Achieving a balance between indoor environmental efficiency and occupant comfort remains a critical challenge for library management. This research underscores the importance of understanding and improving IEQ in libraries to enhance occupant experiences. The findings offer valuable insights that can inform future library design and operational strategies aimed at optimizing the environment for both occupant satisfaction and functional efficiency. Ultimately, this study contributes to a deeper understanding of the role of IEQ in enhancing library spaces, providing essential guidance for future improvements in library planning and management.

Keywords: Academic Library, Acoustic Quality and Indoor Air Quality, Indoor Environmental Quality (IEQ), Thermal Comfort

I. INTRODUCTION

The indoor environment plays a crucial role in human well-being, as individuals spend a significant portion of their time indoors. As a result, Indoor Environment Quality (IEQ) directly influences health, productivity, and overall quality of life. Poor IEQ can lead to discomfort, health issues, decrease cognitive performance, and reduced efficiency (Mujan et al., 2019). Therefore, ensuring optimal IEQ is essential in public buildings, particularly in libraries, where users engage in reading, studying, and intellectual activities. Generally, IEQ encompasses key factors such as thermal comfort, air quality, lighting, and noise levels (Kakoulli et al., 2022). In this regard, libraries serve as intellectual and social hubs, accommodating a diverse range of users seeking a conducive environment for focused work. Thus, a well-maintained indoor environment enhances user comfort, concentration, and overall experience. To achieve this, addressing IEQ challenges in libraries spaces is essential to support learning and ensure a pleasant atmosphere for users. One of the most important aspects of IEQ is air quality. Proper ventilation systems are necessary to maintain a continuous flow of fresh air while effectively removing pollutants and odors. Moreover, the presence of airborne contaminants such as dust, allergens, and volatile organic compound (VOCs) can negatively impact occupant health and must be carefully monitored. By doing so, maintaining good air quality ensures a safe and comfortable environment for library users. Besides air quality, lighting is another critical component of IEQ. For instance, a well-designed lighting

system ensures sufficient illumination for reading and studying, reducing eye strain and enhancing user experience. In particular, natural light is highly beneficial in library settings, as it fosters a welcoming and visually comfortable atmosphere. However, artificial lighting should be carefully selected to minimize glare and shadows while providing adequate brightness. According to Aflaki et al. (2023), artificial lighting negatively affects students' satisfaction in educational spaces, whereas poor acoustic conditions reduce both satisfaction and productivity. Studies by Veitch (2020) indicate that well-balanced lighting contributes to improved mood, concentration, and reading comfort. Similarly, thermal comfort is equally important in libraries, as users often spend extended periods studying and reading. To maintain this, an optimal temperature range, controlled humidity levels, and proper airflow must be ensured (ASHRAE, 2021). In addition, ergonomic furniture and well-designed seating arrangements enhance user comfort by minimizing discomfort and health risks associated with prolonged sitting (Al-Horr et al., 2016). On a broader scale, research indicates that in the United States and the United Kingdom, a substantial portion of energy consumption is dedicated to maintaining comfortable indoor environments (Aflaki et al., 2023). Therefore, by prioritizing air quality, lighting, thermal comfort, and noise, libraries can create an environment that fosters learning, concentration, and intellectual engagement. Despite the significance of this issue, comprehensive research assessing the impact of IEQ on library users remains limited. Hence, addressing this gap through further studies will help optimize library environments and improve overall experience for users.

IX. THE METHODOLOGY

The primary data sources were extracted from SCOPUS, Science Direct, and Google Scholar for additional sources. SLR analysis is described as the process of analysing and synthesizing a large body of literature to detect recurring patterns and identify key themes, thereby ensuring the validity and reliability of the findings (Rouhani et al., 2024). As part of this investigation, the findings will be analysed and interpreted to provide recommendations for future research on IEQ. The works of literature were chosen based on several selection criteria: 1) publications from 2016 to 2024, 2) the use of the keyword "indoor environmental quality" in the content, and 3) papers that focus on academic libraries worldwide. The study was focused to IEQ factors affecting the occupancy and comfort condition of future improvements in Malaysia academic libraries. There were 73 results were retrieved from the database, including 3 from Scopus, 11 from Science Direct, and 59 from Google Scholar. After removing duplicates and scanning all abstracts to remove irrelevant articles, 8 articles were identified for review. All 9 articles were grouped into four themes according to the factors of IEQ: Indoor Air Quality, Thermal Comfort, Lighting Comfort and Acoustic Quality.

Table 1.0 Documents to a theme table of the SLR analysis

	Indoor air quality	Thermal comfort	Lighting comfort	Acoustic quality
Zhang (2019)	√	√	√	√
Akanmu, Nunayon & Eboson (2021)		√	√	√
Hong, Kim & Yang (2021)		√	√	√
Majidi, Saradj & Khanmohammadi (2023)		√	√	√
Aflaki, Esfandiari & Jarrahi (2023)	√	√	√	√
Zha et al (2023)	√	√	√	
Abulude & Ademilua (2024)	√			
Gbotoso, Abulude & Ademilua (2024)				√
Hou et al (2024)	√	√	√	√

X. RESULT AND FINDING

A. Indoor environmental quality (IEQ) in academic library

Al-Horr et al. (2016) define Indoor Environmental Quality (IEQ) as the overall quality of a building's environment concerning thermal comfort, health, and occupant well-being. Many complex and interrelated parameters influence IEQ. Therefore, understanding the sources of indoor environmental discomfort and addressing them during the design phase can help prevent various issues. By optimizing IEQ sub-components,

building designers can enhance building value and occupant satisfaction. IEQ does not have a precise or universally agreed-upon definition. In general, Indoor Environmental Quality (IEQ) includes key elements such as Indoor Air Quality (IAQ), thermal comfort, acoustic quality, and lighting conditions, all of which play a crucial role in influencing the health, well-being, and comfort of occupants (Wu, Liu, & Kong, 2023). However, Ortiz et al. (2020) argue that IEQ does not account for psychological effects or individual physical factors, such as age, medical conditions, and natural bodily deterioration, since these elements are difficult to quantify. Nevertheless, thermal comfort, indoor air quality, acoustic quality and lighting quality remain the primary environmental factors in determining IEQ. Similarly, Smith et al. (2018) define IEQ primarily in terms of its impact on building occupant health and comfort. Their findings indicate that IEQ encompasses air quality, thermal comfort, lighting, and acoustics, all of which contribute to overall well-being in indoor spaces. Thus, maintaining high IEQ is crucial for preventing health concerns and enhancing comfort, particularly in educational institutions. Moreover, Kumar and Patel (2020) approach IEQ through the lens of cognitive function and productivity. They suggest that IEQ is essential for improving cognitive performance and workplace efficiency, particularly in educational and professional settings. Their concept of IEQ includes air quality, thermal comfort, ventilation, and the presence of contaminants, all of which directly influence cognitive abilities and productivity. According to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE, 2021), IEQ comprises air quality, access to daylight and outdoor views, acoustic conditions, and occupant control over lighting and thermal comfort. These aspects are fundamental to establishing an environment that fosters well-being and productivity. Furthermore, recent studies highlight the increasing complexities and significance of IEQ. Langer et al. (2022) argue that improving IEQ leads to better health outcomes and higher productivity in office environments, reinforcing the need for comprehensive IEQ management. Likewise, Dehghan et al. (2021) demonstrate that enhanced IEQ can reduce stress and improve mental health in building occupants. These studies suggest that investing in high-quality indoor environments is not only beneficial for occupants' well-being and comfort but also cost-effective in the long term.

B. Academic library definition

An academic library is a library affiliated with a higher education institution that serves two primary functions which is supporting the curriculum and facilitation research for faculty and students. According to Tarango et al. (2023), academic libraries play a crucial role in providing users with access to knowledge, directly contributing to informational growth. By acquiring and curating valuable resources, the libraries address key ontological and epistemological aspects related to value theory and critical training. In Malaysia, academic libraries are vital to higher education institutions, supporting both educational and research objective. As noted by Ismail and Salleh (2021), these libraries provide access to diverse resources, including books, journals, digital databases, and multimedia materials, all essential for academic study and research. Additionally, they offer various services such as information literacy programs, research support, and study spaces that enhance academic experience (Ng et al. 2019). Furthermore, Ahmad et al. (2020) emphasize that academic libraries contribute significantly to academic performance by offering personalized resources and tailored assistance to students and researchers. Moreover, academic libraries have a profound impact on academic success and research productivity. Research by Chien and Lim (2021) highlights that the library supports student achievement by providing essential materials and services for coursework, research projects, independent study and collaborative learnings. The availability of research databases and scholarly journals enables them to access high-quality information, which is critical for academic writing and publication.

C. Importance of IEQ in library

Indoor Environmental Quality (IEQ) plays a crucial role in libraries as it directly impacts occupant comfort, health, and productivity. Libraries serve as learning hubs where students, researchers, and the general public engage in intellectual activities that require concentration and minimal distractions. Poor IEQ, particularly in terms of air quality, thermal comfort, lighting, and acoustics, can lead to discomfort, decreased cognitive performance, and even health issues such as eye strain, fatigue, and respiratory problems (Kamaruzzaman et al., 2020). Moreover, Choi et at. (2019) highlight that inadequate ventilation and poor indoor air quality (IAQ) can lead to higher carbon dioxide (CO_2) levels, which negatively affect cognitive function and user experience. In addition, Jamrozik et al., (2019) emphasize that natural daylight plays a significant role in enhancing visual comfort and minimizing eye strain, whereas poor acoustic conditions can cause distractions, ultimately lowering productivity. Given that libraries are designed to support learning and research, optimizing IEQ is essential to creating a conducive environment that enhances user satisfaction, promotes well-being, and supports academic success.

D. Significance of IEQ in library

The significance of Indoor Environmental Quality (IEQ) in libraries extends beyond occupant comfort, influencing long-term sustainability, operational efficiency, and academic performance. Proper maintenance of Indoor Environmental Quality (IEQ) contributes to healthier indoor environments, mitigating the risks of Sick Building Syndrome (SBS) and other health issues that may negatively affect library users (Shika et al., 2023). Moreover, optimizing IEQ enhances energy efficiency by improving ventilation, thermal regulation, and lighting systems, which contributes to cost savings and environmental sustainability (Kamaruzzaman et at., 2020). Libraries also serve as vital academic hubs, and poor IEQ can impact knowledge retention, concentration, and overall learning outcomes (Dehghan et al., 2021). By prioritizing IEQ, libraries can foster an optimal environment that supports intellectual engagement, enhances productivity, and ensures long-term sustainability in building operations.

E. Factors of IEQ in library

Several factors contribute to Indoor Environmental Quality (IEQ) in libraries, influencing user comfort, health, and productivity.

Table 2.0 The literature search on the factors influences the occupancy and comfort conditions in libraries.

Author	Year	Factors of IEQ in libraries research
Indoor Air Quality		
Hou et al	2024	Thermal quality perception, visual quality perception and indoor air quality perception have a substantial impact on two factors, while the interaction between air quality and noise perception was not significant, temperature and sound pressure interacted notably with air quality perception.
Abulude & Ademilua	2024	Air quality is a critical aspect of indoor environments, influencing the health and well-being of individuals who spend significant time indoors.
Hong, Kim & Yang	2022	The objective measurement of indoor air quality (IAQ) the occupants felt slightly cool, average humidity level of the common's areas, 34.74%, is in a comfortable range. The indoor CO2 average level is 657.86 ppm, which is lower than 1,200 ppm, acceptable in an occupied space
Acoustic Quality		
Akanmu, Nunayon & Eboson	2021	Study spaces in the libraries had background noise levels exceeding the recommended threshold limit value of 45 dB, the highest value reaching up to 72 dB during an afternoon period
Gbotoso, Abulude & Ademilua	2024	The detrimental impacts of noise pollution on library patrons, encompassing cognitive, psychological, and physiological consequences. comprehensive strategies for noise reduction and management to overcome negative effects on learning outcomes, user satisfaction, and overall well-being
Hong, Kim & Yang	2022	The average measurements of noise of spaces do not meet the comfortable levels according to the standards, the average is 59.44 dB, which is higher than 45dB suggested in open-plan offices by ASHRAE Handbook (Owen, 2011). European Standard (EN) (2007) suggests 35dB–45dB
Hou et al	2024	Acoustic quality is the critical role that these elements play in shaping user satisfaction, especially for intense study and concentration. Acoustic quality and interior design are directly impact on the user experience,

		particularly in areas designated for studying and concentration
Thermal Comfort		
Aflaki, Esfandiari & Jarrahi	2023	Ensuring thermal comfort involves balancing energy efficiency with maintaining a suitable indoor environment for all users.
Zhang	2019	Indoor environmental quality had a greater impact on the performance and satisfaction of occupants; their satisfaction should first be improved by the enhancement of the indoor environment, hence will improve their performance.
Akanmu, Nunayon & Eboson	2021	The average temperature distribution in the three libraries ranged from 26 to 32 °C. The CIBSE standard 2006 states that the comfort zone conditions for a library space need the air temperature to be between 24 °C and 25 °C and relative humidity between 40% and 70%. unsatisfactory thermal environment has on library users and collections, especially in the hot and humid climate of tropical regions
Hou et al	2024	Thermal quality perception, visual quality perception and indoor air quality perception have a substantial impact on two factors, while the interaction between air quality and noise perception was not significant, temperature and sound pressure interacted notably with air quality perception.
Lighting Comfort		
Liu et al	2021	The various window types of influence illumination distribution and daylight glare, for optimal lighting conditions. The findings indicate the size and shape of windows important in determining indoor lighting levels and glare, the that larger windows can contribute to higher glare levels.
Zha et al	2023	IEQ criteria not only contribute to students' overall well-being but also have a significant impact on their academic performance, highlighting the importance of a conducive living and learning environment.
Hong, Kim & Yang	2022	The average measurements of indoor lighting of the spaces do not meet the comfortable levels according to the standards, about 460 lux, in the learning commons lower than 500 lux as recommended in ASHRAE.
Aflaki, Esfandiari & Jarrahi	2023	Natural light is favored for its positive impact on mood and vitality, while artificial lighting must be properly planned to minimize glare and guarantee appropriate illumination throughout all library spaces.
Akanmu, Nunayon & Eboson	2021	The illuminance was not enough to carry out visual tasks (< 250 lux) and since some of the lighting points had stopped functioning. The weak indoor daylight causes serious fall-off of illumination. The insufficient illuminance level in the three libraries, the users would suffer various visual related discomforts such as eyestrain, irritation of the eyes, blurred vision, headache, and others.

F. Effects of IEQ on libraries' occupancy and comfort conditions

Indoor Environmental Quality (IEQ) significantly influences library users' well-being and productivity by affecting health, comfort, and overall academic performance. Poor IEQ conditions, including inadequate lighting, poor air quality, excessive noise, and thermal discomfort, can lead to reduced concentration, fatigue, and health issues, ultimately impacting learning and research activities (Akanmu et al, 2021). Proper lighting

enhances visual comfort and reduces eye strain, while inadequate illumination contributes to fatigue and decrease efficiency (Kossmann et al., 2021). Similarly, noise disruptions can hinder focus and productivity, whereas effective acoustic design promotes a conducive study environment (Jiang et al., 2022). Thermal comfort, which involves maintaining appropriate temperature and humidity levels, is another essential factor of IEQ in libraries. Extreme temperature fluctuations can cause discomfort and decrease productivity among library users. Zhang et al. (2022) found that maintaining optimal thermal conditions is crucial for user satisfaction and the preservation of library materials. Indoor air quality (IAQ) is a critical aspect of IEQ that affects the health and well-being of library users. Poor IAQ characterized by high levels of pollutants such as volatile organic compounds (VOCs), carbon dioxide (CO_2) and particulate matter, can lead to headaches, respiratory issues, and cognitive decline (Wang et al., 2019). Research suggests that libraries with well-maintained IAQ, achieved through proper ventilation and air filtration systems, create a healthier and more comfortable environment, ultimately enhancing user productivity and satisfaction (Gao et al., 2020).

CONCLUSION

For the conclusion, Indoor Environmental Quality (IEQ) and its significance in library environments. It begins by defining IEQ and describing its components, which include indoor air quality, acoustic quality, thermal comfort, and lighting comfort. Each component is described in terms of its influence on health, comfort, and productivity, with a specific emphasis on libraries. The review highlights the need for good IEQ in libraries to promote ideal learning and working conditions for the occupant and comfort conditions.

ACKNOWLEDGMENT

With profound gratitude, the author extends the appreciation to the academic project supervisor, Programme of Building Surveying and UiTM Perak Branch for the invaluable guidance, unwavering support, and for funding this publication.

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A REVIEW ON ADMINISTRATION OF SMALL ESTATE DISTRIBUTION: FACTORS CONTRIBUTING TO DELAY OF DISTRIBUTION OF IMMOVABLE PROPERTY IN ISLAMIC INHERITANCE IN KEDAH

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ABSTRACT

The majority of Muslims encounter significant challenges when attempting to assert their rights particularly in the distribution of immovable properties. Muslims are increasingly facing issues with unclaimed inheritance properties and frozen assets. Unclaimed property volumes have been steadily increasing over the years. Currently Malaysia has over 100 billion ringgits in unclaimed estate where Kedah recorded the highest number of arrears with 13,423 cases, highlighting the severity of the issue. Determining the reasons behind the delay in the distribution of the deceased's inheritance property is therefore essential. The administration of Islamic inheritance includes a process that crosses various stages of the process and through various procedures, there are specific issues at each level. The institutions involved in the management and administration of Islamic inheritance is JKPTG a department that manage a small estate in Malaysia. The aim of this research is to explore the factors contributing to delay in Islamic inheritance distribution in Kedah which specifically focus on immovable property such as land and building for small estates distribution. The research employs reviewing relevant literature from conference papers, journals newspapers and related websites. The finding acknowledges that, lack of knowledge and understanding, unawareness of heirs on processes and procedures to follow, unwillingness to cooperate between heirs involved, administration and distribution process, high cost and long-term of process in Islamic inheritance distribution to be the primary causes of the problem. Addressing these challenges is crucial for improving the efficiency of Islamic inheritance distribution and reducing the backlog of unclaimed estates.

Keywords: Small Estate Administration, Islamic Inheritance, Delay in Estate Distribution, Immovable Property Distribution

I. INTRODUCTION

Inheritance consists of two statuses namely Non-Islamic Inheritance and Islamic Inheritance (Nik Erman, 2023). Based on Islamic law principles, Islamic inheritance distribution is a method of dividing a deceased person's assets among their heirs. “Faraid” is an Islamic method of dividing inheritance. It is obtained from a deceased person who left heirs who are entitled to inherit under Sharia Law after the deceased's remains have been cared for, his debts which is debts to God for example zakat, hajj, fidyah, and atonement, and debts to humans that have been settled, and his will (if one exists) has been executed. Faraid, Wasiyah (wills), Hibah (gift) and Waqf (charity) are the dimensions of estate planning tools for muslims. Proper Islamic estate planning can assist Muslims guarantee that their assets are transmitted easily to their heirs. When a Muslim dies, the Islamic Law of Inheritance, or Faraid, directs the distribution of the deceased's estate (Wan Nurliyana, 2023).

Estate administration, which deals with the management of the deceased's estate, is a fundamental component of inheritance. When someone passes away, their estate is left unattended (Nasrul & Mohd Salim, 2018). When it comes to inheritance, there are two essential components which are the assets of the deceased person and the beneficiaries of those assets (Amrullah et al., 2021). Islamic law stipulates that heirs are obligated to take immediate responsibility on any piece of land or property that was left by a deceased proprietor (Zainul Abidin

et al., 2022). The majority of Muslims encounter a major barrier when attempting to assert their Islamic inheritance rights is the delay in doing so. This will result in an accumulation of unclaimed estates and frozen assets after the matter. Delays in inheritance distribution can lead to an increase in unclaimed assets in Malaysia, whether from an economic or legal point of view and social society if it is not addressed well (Bibi Nur Adila Zulkafli, 2016). Frozen property refers to a person's property that is still withheld from any transactions or matters of distribution to heirs after the death of the property owner, before the whole process of estate administration is done (Ghazali et al., 2023).

In Malaysia, institutions that handle inheritance cases is Department of Director General of Lands and Mines, Ministry of Natural Resources and Environment (JKPTG). This unit specifically addresses intestate cases involving small estates, which consist of either immovable property or a combination of immovable and movable assets, where the total value is no more than two million ringgits (Nasrul & Mohd Salim, 2018).

Inheritance remains a problem in Malaysia, where it is estimated that more than RM100 billion in frozen and unclaimed property is recorded, 90 percent of which belongs to Malay Muslims (Malaysia Tribune, 2023).

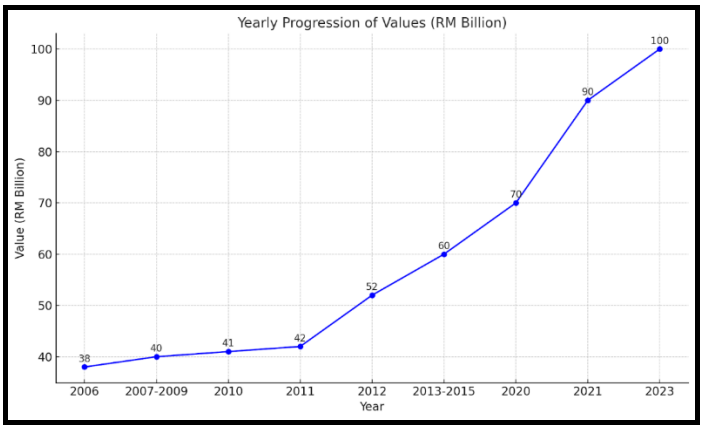


Figure 1.0 : Graph depicting the yearly progression of values (in RM billion) from 2006 to 2023
Sources : Accountant General's Department of Malaysia

The graph depicts the progression of values (RM billion) from 2006 to 2023, demonstrating a consistent increase over time, with some notable growth patterns. The graph indicates changes in economic conditions, policies, or the effectiveness of wealth management systems by highlighting both periods of steady growth and periods of rapid escalation.

In Malaysia, the issue of arrears has become a pressing concern, particularly in certain states with high reported cases. Kedah recorded the highest number of arrears with 13,423 cases (Rohaniza Idris, 2022).

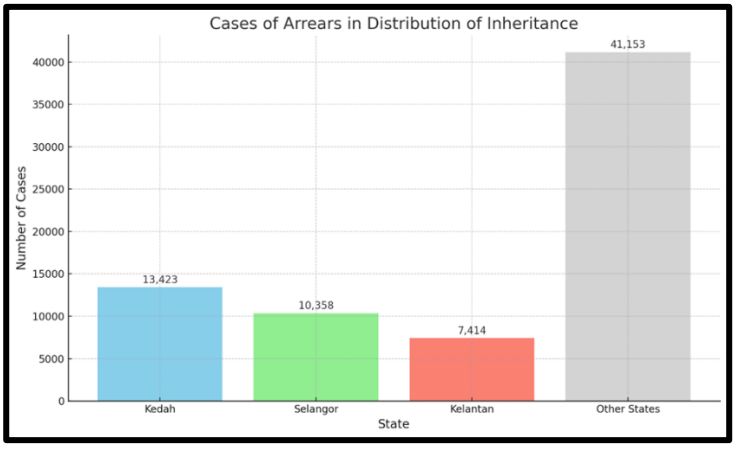


Figure 2.0 : Number of cases of arrears in the distribution of inheritance
Sources : Berita Harian Online, 2022

The aim of this research is to explore the key factors contributing to delay in Islamic inheritance distribution in Kedah which specifically focus on immovable property such as land and building for small estates

distribution which often involve complex procedures. The study investigates how heirs' attitudes, legal complexities, and administrative procedures contribute to the lengthening of estate settlement procedures. The objective of this research is to determine the factors that contribute to the delay of immovable property distribution of small estate in Islamic inheritance distribution.

Consequently, it is crucial to understand the significance of arranging the distribution of wealth prior to death in order to prevent the beneficiary from experiencing difficulties in overseeing the allocation of inheritance properties (Abdul Rashid et al., 2010). Understanding the factors that contribute to inheritance delays is critical for reducing the backlog of unclaimed estates, increasing economic productivity, and ensuring equitable wealth distribution among Muslim heirs. By addressing these issues, this study contributes to Malaysia's development of a more efficient and transparent estate management system.

II. LITERATURE REVIEW

Delays in estate administration are a major concern for both authorities and the public. Delays have led to an alarming increase in unclaimed assets in recent years, highlighting the need for an immediate solution (Nasrul & Mohd Salim, 2018). Muslims are increasingly facing issues with unclaimed inheritance properties and frozen assets. These valuable assets have been frozen and are unproductive. Unclaimed property volumes have been steadily increasing over the years. The Muslim community in Malaysia continues to face unresolved issues due to an increase in frozen assets (Ikhwan Hafiz, 2022). In 2023 where it is estimated that more than RM100 billion in frozen and unclaimed property is recorded in which saw an increased in number compared from the past years (Malaysia Tribune, 2023).

2.1 Estate distribution division

The Estate Distribution Section, Bahagian Pembahagian Pusaka (BPP) operates 36 units in Peninsular Malaysia, implementing government land administration under the Department of Land and Mines Director General, Ministry of Natural Resources and Environment. For districts without units, small estate applications are submitted and accepted through the District Land Office. Accepting inheritance management applications at the Land Office simplifies administration and prevents community confusion (Kamariah et al., 2022). This unit specifically addresses intestate cases involving small estates, which consist of either immovable property or a combination of immovable and movable assets, where the total value is no more than two million ringgits (Nasrul & Mohd Salim, 2018). The Estate Distribution Division's main source of authority for handling estate administration and issuing letters of representation and distribution orders is the Small Estate (Distribution) Act of 1955. A number of changes were made to the Act to strengthen the unit's role, one of which was raising the maximum amount of estate that the unit could handle from RM600,000 to RM2,00,000 (Mohd et al., 2022).

The Estate Distribution Division, like the High Court, is required by law to give out letters of representation (Amrullah et al., 2021). In this case, they are called Letters of Administration (Form F of the 1955 Act). Nevertheless, Administrative Letters are only issued to an administrator who was appointed with the consent of all heirs in exceptional circumstances. After receiving the letters of administration, an administrator is granted the authority to gather the deceased's assets, settle their debts, and distribute their estate to their rightful heirs. In simple situations, the land administrator will simply issue the beneficiaries a distribution order (Form E), which has two immediate consequences. In the first, the beneficiaries are listed in the land title, which pertains to immovable assets like land. Each entitled beneficiary can get their secured portion of the movable assets by submitting a copy of Form E to the related institution (Alam Shah et al., 2022).

III. METHODOLOGY

This research employs a desk study methodology, which involves a comprehensive analysis and examination of secondary data sources (TJ Kiely, 2024). The desk study method is chosen for its ability to effectively gather comprehensive information from the existing literature, in order to investigate the factors that contribute to delays in the distribution of immovable property under Islamic inheritance law, specifically in Kedah. The difficulties of Islamic inheritance distribution in Malaysia are examined in this study using secondary data. Conference papers, scholarly journals, newspapers, government reports, and pertinent internet sources are all part of the research's extensive literature review. The primary objective is to identify the underlying factors behind the delays in estate distribution which consist of lack of knowledge and understanding of heirs, unawareness of heirs on processes and procedures to follow, unwillingness to cooperate between heirs involved, administration and distribution process, high cost and long-term of process in Islamic inheritance distribution. The data for this study is derived from document analysis. The main sources that were reviewed included academic journals and conference papers. These sources offer theoretical frameworks, empirical findings, and scholarly discussions about Islamic inheritance and estate distribution delays. Statistical data,

expert opinions, and recent developments regarding unclaimed estates and the backlog in the inheritance distribution process have been featured in newspaper articles and reports from credible sources. Furthermore, authoritative insights into the procedural aspects of estate administration are provided by government publications and legal documents, including reports from the Department of Director General of Lands and Mines (JKPTG) and the Small Estate (Distribution) Act of 1955. Additionally, pertinent websites function as supplementary sources to verify the results and guarantee the inclusion of current information regarding inheritance management systems. In order to uphold academic integrity and prevent plagiarism, all sources are appropriately cited. This research provides a thorough, literature-based analysis of the reasons and effects of delays in Islamic inheritance distribution by using a desk study methodology. The results offer important new information about possible administrative and policy changes that could improve Malaysia's estate distribution system's effectiveness.

IV. FINDING AND DISCUSSION

The finding indicates that the distribution of Islamic inheritances in Kedah is delayed by a several of critical factors, particularly in the case of small estates that involve immovable properties, such as land and buildings. These factors encompass lack of knowledge and understanding of heirs, unawareness of heirs on processes and procedures to follow, unwillingness to cooperate between heirs involved, administration and distribution process, high cost and long-term of process in Islamic inheritance distribution. In order to facilitate a more efficient inheritance distribution process in accordance with Islamic law, the study emphasizes the necessity of systematic reforms, increased awareness, and improved coordination between relevant authorities to address these factors.

4.1 Lack of Knowledge and Understanding

It is imperative that Muslims in Malaysia are fully informed about the Islamic Inheritance Law, also known as Faraid, in order to stop the ongoing rise in unclaimed properties among Muslims (Nasir Zulkifli et al., 2018). Moreover, the distribution of inheritance properties is delayed and negligent for a number of reasons and factors. The main factor related is because of the lack of knowledge and understanding by people who live in the state of Kedah. They continue to ignore the management of inheritance applications because they do not have Faraid knowledge and matters related to it (Aliesya Mohd Yusof & Zuhaili Saiman, 2024). This mindset and attitude are common among all people who live in the rural areas compared to those who live in urban areas (Shahrul Nizam, 2024). People who live in rural regions are more likely to have such beliefs because they are less exposed to information about how property is distributed. As well as that, the Malay community has limited the application of Faraid rules to estate distribution, making their implementation impractical (Mohd Shahril, 2016). Indeed, it is clear that the general public still lacks knowledge and understanding of Faraid's Islamic concept of property divisions (Saujan, 2022). Muslim society possesses limited comprehension of Islamic inheritance laws, regardless of their background, profession, or sector. Some Muslims possess a wealth management strategy that does not align with Islamic principles of wealth distribution (Ibrahim, 2024). The purpose of Faraid's rule is to determine the rights of beneficiaries and their portions, not to divide land into small fractions. In point of fact, the rule's distribution determination does not state that the estate should be divided among family members or beneficiaries in accordance with their respective portions (Mohd Shahril, 2016). Furthermore, when the property owner takes their inheritance for granted by keeping their heirs in the dark about the property they own, the heirs will not be aware that the inherited property even exists. This will also cause issues with inheritance division (Shafie et al., 2016).

4.2 Unawareness of heirs

Beneficiaries' attitudes and ignorance are said to be among the factors that contribute to estate neglect. The lack of inheritance knowledge among beneficiaries or the general public is the cause of the omission (Ali & Ahmad, 2021). The community is unconcerned about this issue and believes that settling the estate is a simple task (Wajis et al., 2018). The eldest son is considered responsible to handle and make the application although in order to carry out the distribution of this inheritance, all of the heirs involved must collaborate together to settle it whatever happens (Shafie et al., 2016). Apart from that, the thing that prevents the process of dividing the inheritance from being completed immediately is misunderstanding where they are understood to respect the deceased. Issue of inheritance is a very sensitive issue to discuss, especially by the Malay community living in rural areas. A situation such as this quietly impedes the heirs' commendable endeavour to fulfil their duties, given that they are cognizant of and understand the circumstances. Sadly, they are thought to be rapacious and obsessed with the deceased's remains, which causes family conflict and arguments (Bibi Nur Adila Zulkafli, 2016). According to preliminary research, applications for estate administration and distribution are frequently neglected and long overdue after a death. On the contrary, there are numerous estate settlement cases that require decades to settle.

4.3 Administration and distribution process

Ensuring that the administration and management system adheres to the Islamic system can guarantee that the community's and the country's needs are met. To achieve a good inheritance management and management system, the administration and management must address some of the issues that are causing the community to struggle. Following the controversy surrounding Malaysia's property administration system, which is said to be ineffective and has resulted in billions of dollars in property arrears (Rohaniza Idris, 2022). Inheritance is divided into three, namely large inheritance, small inheritance and simple inheritance. For large inheritance, applications to get a power of attorney are made in the Civil High Court. Next, applications for the division of Small Inheritance property can be made at the Inheritance Division Unit/Office. Land Application for the division of this simple estate must be made to the Director General of Perbadanan Amanah Raya Berhad for Inheritance consisting of movable property only without a will such as money not exceeding RM 600,000.00 (Alam Shah et al., 2022). Property loss factors, on the other hand, are not claimed because of the complicated process and the number of jurisdictions to navigate. This is due to the authorities' desire for the inheritance to be distributed in a convoluted manner. To avoid fraud, the estate is distributed to the heirs who are legally entitled to it. What makes the process more complicated is the applicant cannot provide the sufficient document related to the management process which makes the duration of the property allocation longer (Bibi Nur Adila Zulkafli, 2016).

4.4 Unwillingness to cooperate between heirs involved

Most heirs refuse to cooperate in managing the distribution of this inheritance because they want to conquer all of the deceased's property without sharing it with other heirs who deserve their own portion (Bibi Nur Adila Zulkafli, 2016). This is due to the heirs' greedy attitude, which becomes more apparent when they know and find out how large and valuable the deceased's property is. With respect to the attitude dilemma, the fact of the matter is that this factor is the cause of unresolved inheritance scenarios (Haslin et al., 2022). Previous studies have made the same claim. Obviously, this will cause a lack of tolerance among the heirs in managing the division of the inheritance thus further delaying the process in Islamic inheritance distribution (Mohd Shahril, 2016). The disagreements often lead to fights between beneficiaries, who are usually siblings, over who gets to own the land (Abdullah, 2021). Failure to manage the inheritance will result in assets not being developed and used until the inheritance is divided and property is transferred from the name of the deceased to the name of the deceased's rightful heirs (Bibi Nur Adila Zulkafli, 2016). Other than that, the problem that frequently arises among heirs is also about who is entitled and responsible in applying for and managing the process of distributing the inheritance, resulting in disagreements and misunderstandings among the heirs (Bakar et al., 2020). Furthermore, the negative personal attitude that the beneficiaries exhibit can disrupt the smooth administration of the estate (Nasrul & Mohd Salim, 2018).

4.5 High cost in managing inheritance distribution process

Most people who live in rural areas do not have high incomes, especially people who live in the state of Kedah. So, in order to manage the process of dividing the inheritance, they delay it because they do not have sufficient financial constraints, whereas rich people can engage with legal professionals, for example hire a lawyer to manage the property until it is completed, which contributes to significant fees, while the middle class and low-class income lacks the ability to appoint a lawyer, they will continue to remain silent without taking any action (Noordin et al., 2013). When the value of the amount to be claimed after distribution is small, beneficiaries may be reluctant to follow the necessary procedures due to the expenses associated with any transaction or application to claim the estate. Besides, appraisal and valuation fees may be incurred when determining the value of various assets within the estate which further delays the process for some heirs in obtaining enough money to continue the process of dividing the inheritance (Abdul Rashid et al., 2010b). Other than that, according to the Official Portal of the Kedah Darul Aman District and State Land Office, the fee charged by JKPTG is 0.2% of the total value of property under administration for property values of RM50,001 and above. Claims processed at land offices are less expensive, but few people know this. According to Pembahagian Harta Pusaka Kecil, the Land Office can easily settle Small Estates cases for fees ranging from RM10 to 0.2% of the estates' value.

4.6 Long term process in Islamic inheritance distribution

Although Islamic inheritance distribution is generally intended to be a quick and efficient process, several factors can contribute to it taking a long time (Shafie et al., 2016). The complex family structure and large number of heirs in determining the division of the inheritance to the heirs who deserve their share cause this property division process to take a long time. Furthermore, the amount of inheritance left by the deceased is

substantial, necessitating the completion of numerous legal processes. Complying with legal and administrative requirements, such as obtaining necessary certificates and permissions, can lengthen the process. In some cases, heirs may have to wait for regulatory approval (Abdul Rashid et al., 2010b). When beneficiaries submit an application, the duration from application to final resolution of the case will be prolonged, resulting in an extended distribution of the estate (Haslin et al., 2022). Despite that, the Small Estate Distribution Division Office is cheap, but it takes a very long time to complete because there are too many cases handled (Ahmad Solehin Abd Ghani, 2021). There are also situations where the heirs delay the desire to complete the division of the inheritance dead for months and years and this can contribute to its occurrence layered death among the heirs entitled to inherit (Ansari,2021). Long procedures may also last several years to clear the case of dying intestate, which led to an episode of frozen estate issues and delayed settlement period (Haslin et al., 2022). Assistant Director UPPK Temerloh explains that there are many cases *munasakhat*, which is a layered death that occurs in Alor Setar, Kedah until there is a case involving 27 layers of death that need to be investigated one unity and step by step to give the right to the rightful. Thus, no wonder if there is a claim application for inheritance assets in 1968 that have not yet been received resolved due to layered mortality (Bibi Nur Adila Zulkafli, 2016).

CONCLUSION

In conclusion, in order to ensure that the inheritance properties are distributed in a prudent manner after the death of the heirs, we need to locate an efficient mechanism or tool that can be put into practice, such as Hibah or Wasiat. Additionally, the most critical aspect is the wealth planning and administration of our remaining properties. The preparation of early planning and systematic management is necessary. The circulation of wealth of the deceased was halted following their death until the distribution of inheritance to the entitled heirs was finalized. The timeframe for liquidating assets is contingent upon various factors. This encompasses individual inventory regarding inheritance planning, comprehension of heirs, cost management, and the efficiency of institutions engaged in inheritance administration within the country, specifically for small estates, namely the Small Estate Distribution Section JKPTG. The prolonged duration required to liquidate and allocate the property to its rightful owners results in increased losses for Muslims. Consequently, when an asset is designated as frozen property, the productive components present on the property have not succeeded in generating economic or social advantages for the owners and the public.

ACKNOWLEDGMENT

I would like to thank to the College of Built Environment, Universiti Teknologi MARA Seri Iskandar, Perak for the financial assistance for the study and conference participation. I also want to express my heartfelt gratitude to Department of Built Environment Studies and Technology for their continued encouragement and commitment to academic success. This study would not have been feasible without the institution's dedication for this conference. Furthermore, gratitude extended to the RISM International Surveying Conference for Undergraduates (ISCU) 2025 committee for providing a platform for researchers to share knowledge and network.

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EXPLORING FACTORS AFFECTING ELEVATOR PERFORMANCE: A THEMATIC REVIEW

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ABSTRACT

Elevators are vital as vertical transportation systems in high-rise buildings, ensuring accessibility, convenience, and efficiency in urban living. However, these systems degrade over time, requiring effective maintenance to maintain safe and reliable operation. The poor performance of elevators has a negative effect on occupants' satisfaction and increases the likelihood of safety concerns, which can lead to discomfort and dissatisfaction. Since high rise building occupants rely heavily on elevators for daily mobility, it is important to acknowledge studies have been conducted and have identified the needs for elevator performance improvement. This paper explores the elevator performance research patterns in aging high-rise buildings from 2000 to 2025 using thematic review. The themed review was conducted by examining articles from two electronic databases: SCOPUS and Google Scholar. Information on elevator performance was extracted from 16 studies, which identified three main themes: design factors, technical factors and operation factors. The design factors encompass space, appearance outlook, buffer space design and number of elevators. The technical factor evaluates the car vibration, speed, levelling and door operation. The operation factor addresses waiting time, travel time, number of trips and noise and vibration which are critical to user satisfaction. Future research can build upon these insights to evaluate elevator performance in other contexts, promoting sustainable and efficient property management practices.

Keywords: Elevator, Vertical transportation, High-Rise Building, Satisfaction, Performance

I. INTRODUCTION

More than half of the global population now resides in urban areas, and this proportion is projected to surpass 60% by 2030 (Saroglou *et al*., 2017). As cities become more densely built with increasing numbers of multistory buildings, the need for reliable and efficient elevator performance becomes increasingly critical (Al-Kodmany, 2015). Elevators play a crucial role in the functionality of multi-storey buildings by providing vertical transportation that is fast, convenient, and accessible (Man *et al.,*2025). Their presence enhances the usability of high-rise structures for various occupants, including residents, employees, and visitors. A well-functioning elevator system contributes to the overall operational efficiency of a building, particularly during peak usage times when demand is high. The performance of an elevator is influenced by a combination of design, technology, maintenance practices, and building usage patterns (Strakosch & Caporale, 2010).

The relationship between elevator performance and user satisfaction is closely linked, as users tend to judge their overall experience in a building based on the reliability and efficiency of the elevator system. Frequent delays, overcrowding, or malfunctions can lead to dissatisfaction, decreased productivity, and negative perceptions of the building's management (Paurnami, 2021). In contrast, smooth and timely elevator service contributes to comfort and convenience, which enhances user satisfaction. Therefore, understanding the factors that affect elevator performance is essential in developing strategies to maintain or improve service levels and ensure a positive user experience (Ali & Al-Kodmany, 2012).The objective of this paper is to investigate the factors that influence the performance of elevators. These factors collectively contribute to the efficiency, reliability, safety, and user experience of elevators, which are crucial elements in determining their overall performance. Most past studies tend to investigate elevator performance from isolated perspectives either operational, technical, or design-related. For example, studies may focus on waiting time and travel efficiency (Hangli, 2020; Zubair, 2020), technical conditions like vibration or door opening speed (Wei, 2023; Chen, 2024), or design features such as the number of elevators and spatial arrangement (Chang, 2002; Adak, 2013). However, few studies combine these domains into a single evaluation of user satisfaction. This review aims to address that gap by integrating findings from all three areas, offering a more comprehensive thematic synthesis of elevator performance in residential high-rise buildings.

II. MATERIALS AND METHOD

The articles were first entered into ATLAS.ti 8 software (textual analysis software) and then categorized into the following: 1) author, 2) issue number, 3) periodical, 4) publisher, 5) volume, and 6) year of publication. Table 1 shows the search strings that were used to find relevant literature. As a result, the articles were grouped, allowing them to be evaluated based on their publication year (Table 2) and the pattern of discussion. Sixteen (16) articles were finalized using ATLAS.ti 8 after several rounds of screening. Over the last decade, numerous studies have explored factors affecting elevator performance. Publications on the subject are increasing from year to year. This field of study became popular in 2017 and has continued to progress over time. The final number of articles reviewed (n=16) is relatively small for a thematic literature review. However, this reflects the limited number of studies that address elevator performance from a multidimensional user satisfaction standpoint. A large number of engineering-based articles focused solely on technical simulations or hardware performance without linking to user-centered indicators, and were thus excluded. The limited pool of suitable studies underscores a gap in the literature and validates the importance of this integrated review. This review acknowledges a limitation in the small number of included articles. However, this is not due to a lack of elevator studies, but rather because of the specific scope of this review. Most available studies focus narrowly on mechanical, technical, or simulation models without addressing user satisfaction holistically. This makes the current review a valuable step toward bridging technical and experiential perspectives in elevator system research.

Table 1.0 Search strings from SCOPUS database

IV.	SEARCH STRINGS FROM SCOPUS	TITLE-ABS-KEY ((("elevator" OR "performance" OR "maintenance") AND ("high-rise residential building" OR "apartment" OR "office" OR "commercial")))
		Year: 2000-2025

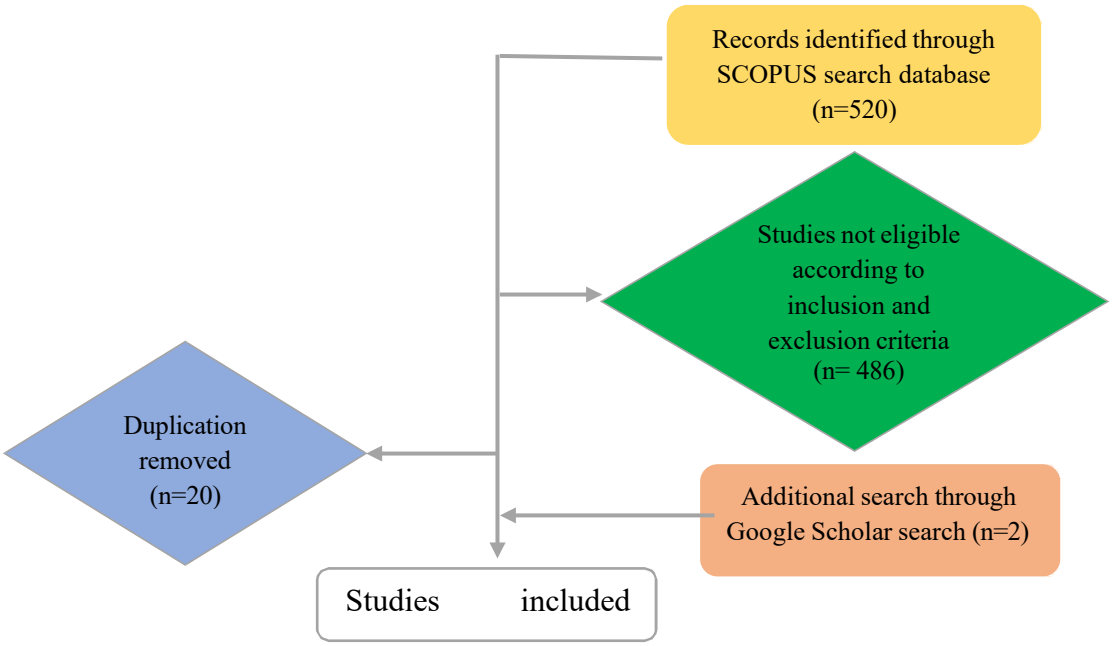


Figure 1.0 Screening profile for thematic review

Table 2.0 Reviewed articles according to year

Year	Articles
2002	1
2013	1
2016	1
2018	1
2019	2
2020	4
2022	3
2023	1
2024	1
2025	1
Total	16

According to Figure 2, a word cloud summary from 16 articles captured the term ‘operation’, ‘technical’ and ‘design’.

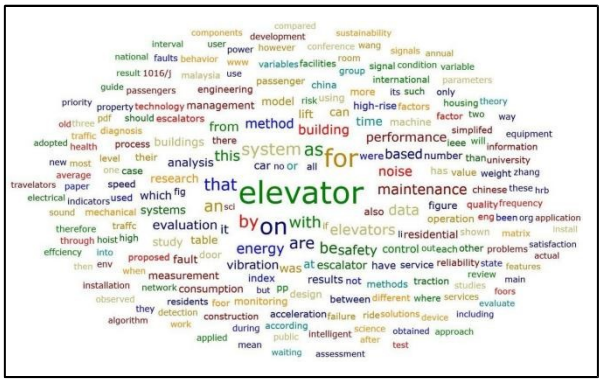


Figure 2.0 Word cloud summary of 16 articles

III. RESULTS AND DISCUSSIONS

Table 3 contains a list of publications and their classification into several subcategories. The trends and patterns generated 12 initial coding after the recall of the 16 articles. After numerous iterations of code merging and re-coding in ATLAS.ti 8, the final patterns and trends revealed three main themes on Operation, Technical and Design on elevator performance in high-rise building.

Table 3.0 Documents to a theme table

Documents	Operation	Technical	Design
Elevator simulator design and estimating energy consumption of an elevator system (Adak *et al*., 2013)		/	/
Comprehensive Energy Consumption of Elevator Systems Based on Hybrid Approach of Measurement and Calculation in Low- and High-Rise Buildings of Tropical Climate towards Energy Efficiency (Ang, *et al.,*2022*)*		/	
Maintenance priority in high-rise housings: practitioners’ perspective versus actual practice (Au Yong *et al*., 2019)	/	/	
Maintenance of lift systems affecting resident satisfaction in low-cost high-rise residential buildings (Au Yong *et al.,* 2018)	/		

Problems in high rise residential building: From management perspective (Azian *et al.,* 2020)	/		
More Analyses for the Service Performance of Elevator Group Systems (Chang & Wu, 2002)		/	
Model-based approach for elevator performance estimation (Esteban *et al.,* 2016)		/	/
Research on the path of residents' willingness to upgrade by installing elevators in old residential quarters based on safety precautions (Guo *et al.,* 2019)	/		
Intellevator: An Intelligent Elevator System Proactive in Traffic Control for Time-Efficiency Improvement (Hangli *et al*., 2020)			/
An Evaluation of Ride Quality in Lift Systems of Selected Public High-Rise Buildings in Abuja, Nigeria (Ibrahim *et al*., 2022)	/		
Reliability and safety of elevators and escalators/ travelators: Past, present and future (Man *et al*., 2025)		/	
Operation performance evaluation of elevators based on condition monitoring and combination weighting method (Niu *et al*., 2022)		/	
Construction Management Solutions to Mitigate Elevator Noise and Vibration of High-Rise Residential Buildings (Oh *et al*., 2020)			/
Performance Evaluation for an Elevator by Analyzing the Vibration Data of the car (Wei *et al*., 2023)		/	
Elevator Health Evaluation Based on Operational State Analysis and D-ANP Method (Chen *et al*., 2024)	/		
Hybrid Performance-Measurement Model of Elevators (Zubair & Zhang, 2020)		/	
Total	**6**	**9**	**4**

Operation Factors

This diagram focuses on the operational aspects of elevators, particularly issues related to waiting times, travel time, number of trips, noise, and vibrations. One of the key studies by Hangli (2020) introduces the concept of an "Intellelevator" system, which aims to improve traffic control in high-rise buildings. Hangli highlights that peak-time traffic congestion within elevators leads to delays, creating vertical bottlenecks in commercial buildings. This results in longer waiting and travel times, affecting overall time efficiency. A similar concern is raised by Zubair (2020), who finds that an increase in response time (which includes both the time spent waiting in the lobby and the time taken to reach the destination floor) causes frustration among passengers. When elevator response time is high, it significantly affects users' perceptions of service quality.

Another crucial aspect of elevator operation is energy efficiency. Ang (2022) provides a detailed examination of how different operational parameters such as elevator speed, the number of trips, load weight, travel distance, and time contribute to energy consumption in both low- and high-rise buildings. The study suggests that a hybrid approach to measuring and calculating elevator energy use can help optimize system performance while minimizing power consumption. These findings highlight the need for better energy management strategies to enhance the sustainability of elevator systems.

Noise and vibration are also significant concerns in elevator operation. Oh (2020) identifies elevator noise and vibrations as factors that create mental anxiety for passengers and affect residential comfort, particularly in high-rise buildings. Excessive vibration during lift operation can make users feel unsafe and uncomfortable. Ibrahim (2022) further investigates this issue in Nigeria, where over 20% of the studied elevators were found to vibrate beyond acceptable levels. The study highlights that excessive interior noise makes approximately 25% of passengers uncomfortable, especially elderly users who cannot take the stairs. Addressing these noise and vibration issues is essential for improving ride quality and overall user experience in elevator systems.

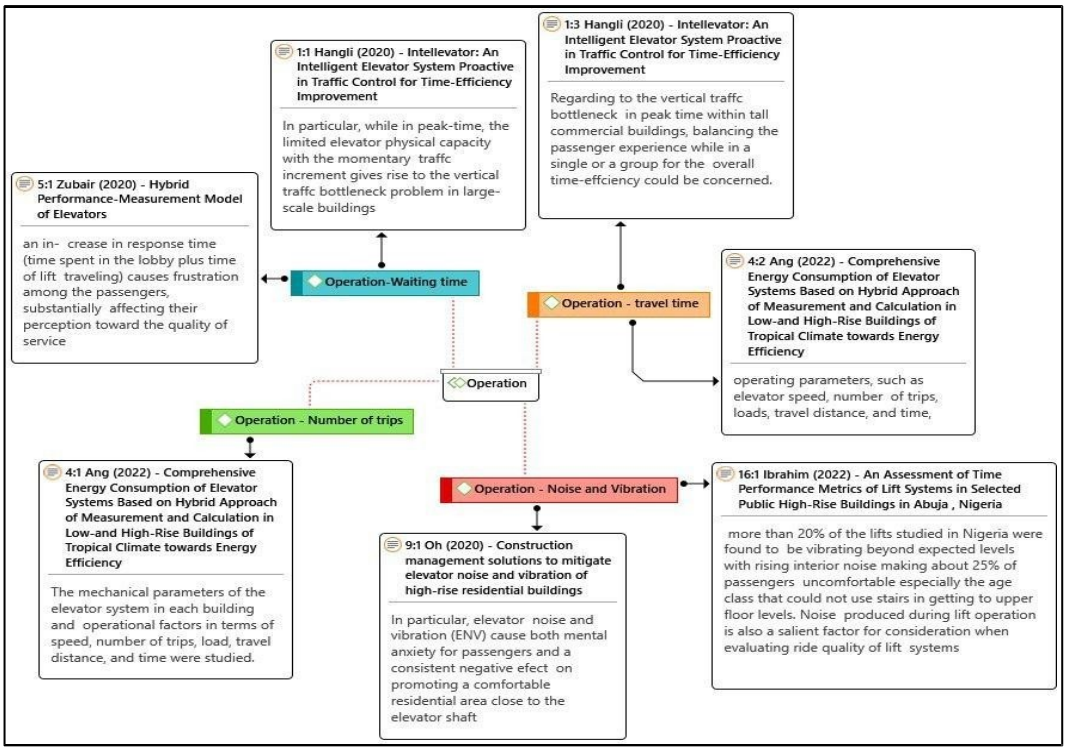


Figure 3.0 Network view of main publication on operation

Technical Factors

This diagram focuses on the technical aspects of elevator performance, particularly in relation to vibration, door operation, and safety mechanisms. Wei (2023) highlights the importance of vibration analysis in elevator performance evaluation. The study suggests that car vibration data can provide insights into system health, enabling maintenance teams to detect potential issues before they lead to failures. Excessive vibration can indicate misalignment, mechanical wear, or other underlying problems that need immediate attention. Leveling accuracy is another key technical factor affecting elevator safety. Zubair (2020) points out that improper leveling increases the risk of passengers stumbling while entering or exiting the cab. Ensuring that the elevator floor aligns correctly with the building floor is crucial for preventing accidents and improving user confidence in the system.

Door performance is also a critical evaluation parameter. Niu (2022) examines the role of door opening and closing speed in overall elevator functionality. The study finds that doors are among the most frequently used components of an elevator system, and their operational efficiency significantly impacts user experience. Slow or malfunctioning doors can cause delays, frustration, and potential safety hazards. Chen (2024) expands on this by analyzing the relationship between door operation and elevator system safety. The study suggests that poorly maintained doors can compromise not only passenger safety but also the overall reliability of the system. The impact of door noise is also discussed in Ibrahim's (2022) study, which finds that excessive noise from door operations can degrade ride quality. For optimal user experience, the sound level produced during door movement should not exceed a specific benchmark. Man (2025) explores reliability and safety measures such as speed limiters and acoustic monitoring systems, which can predict potential failures by analyzing sound data during door operation. These predictive maintenance approaches help prevent unexpected breakdowns and enhance long-term system performance.

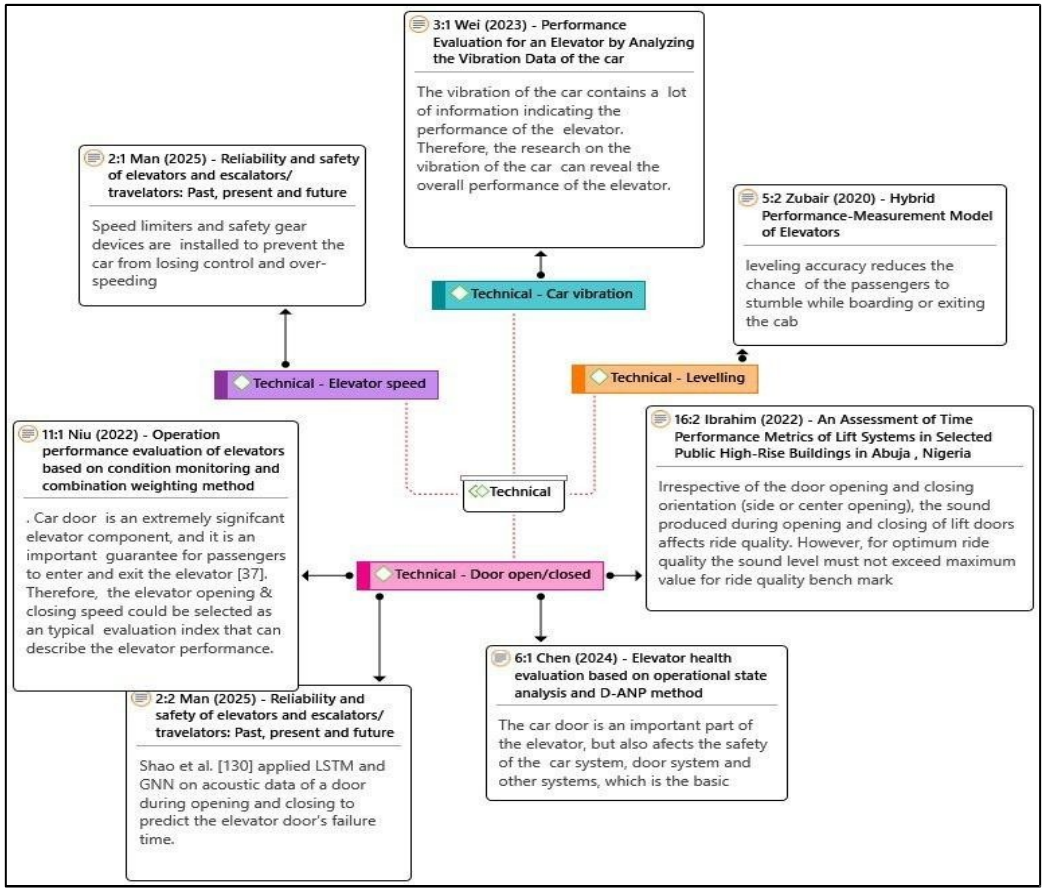


Figure 4.0 Network view of main publication on technical

Design Factors

This diagram explores elevator design elements that influence both functional performance and user experience. Chang (2002) examines the inefficiencies of elevator group systems, noting that most current systems lack the capability to estimate vacant elevator space before dispatching a lift. As a result, many elevators become overloaded before reaching their destinations, leading to increased delays and inefficiency. This study underscores the need for intelligent elevator assignment systems to balance passenger loads more effectively.

The number of elevators in a building is another critical design factor. Adak (2013) investigates the relationship between the number of elevators and energy consumption, concluding that adding more elevators does not necessarily increase energy use.ENV solutions are included in design documents, construction details (such as precision and quality control) must be adjusted based on site conditions. If design flaws are found later, additional modifications are needed. This study defines CM solutions as the integrated management of design and construction processes to effectively reduce ENV in HRBs. (Oh, Y. *et al*., 2020) To mitigate these risks, building managers should implement load-monitoring systems and schedule regular maintenance to detect early signs of strain on critical components. Elevators equipped with smart load sensors and adaptive speed controls can optimize energy use while preventing overloading (Chen *et a*l., 2021). Given these findings, it is evident that a thorough understanding of load dynamics is essential for maintaining reliable, efficient, and safe elevator operations in modern buildings. The study finds that during peak traffic times, elevators move downward with fewer passengers while counterweights balance the load, leading to lower energy consumption than expected. This insight challenges common assumptions about energy efficiency and suggests that strategic elevator placement can improve building performance without significantly increasing energy costs.

User perception of elevator design also plays a key role in satisfaction. Zubair (2020) highlights various aesthetic and functional design elements, including lighting, ventilation, cab motion, and the overall appearance of elevators. These factors influence the comfort and safety of passengers, contributing to the overall perception of service quality. Oh (2020) also discusses how structural-borne noise from elevators can affect residential comfort, emphasizing the need for buffer space design to minimize low-frequency noise transmission. These findings suggest that both visual appeal and noise control should be considered when designing elevators to enhance passenger experience.

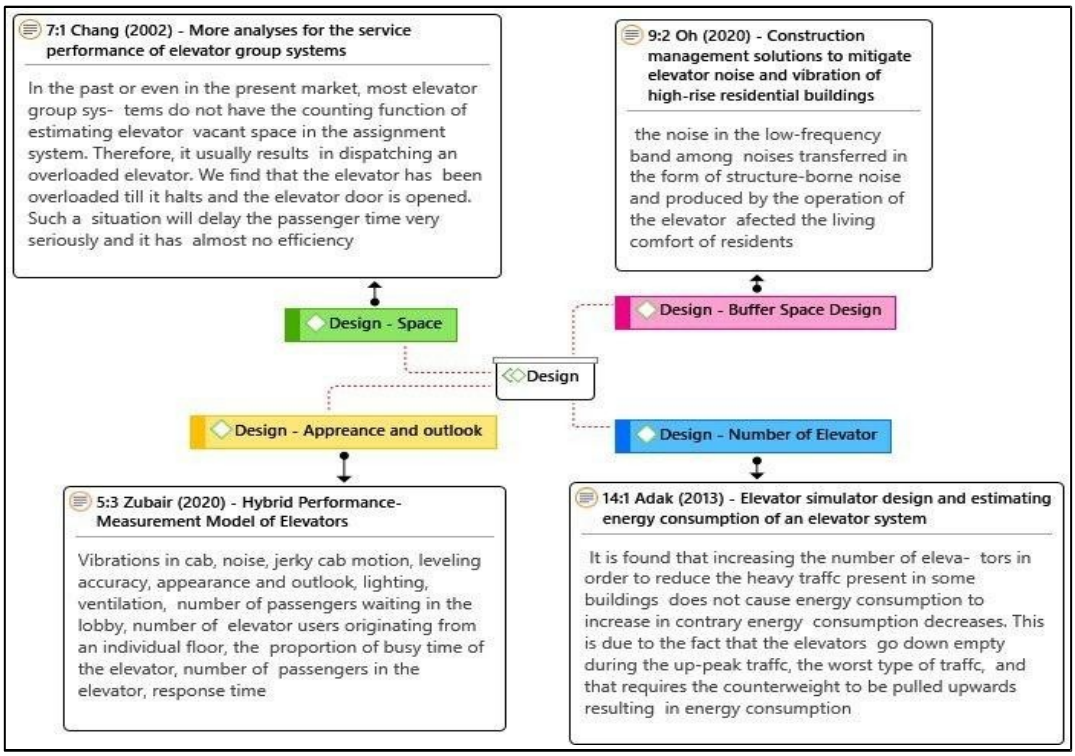


Figure 5.0 Network view of main publication on design

CONCLUSION AND FUTURE STUDIES

The analysis of elevator systems highlights three key factors, operation, technical aspects, and design that significantly impact performance and user satisfaction. Operational efficiency is crucial, as long waiting times, high energy consumption, and excessive noise can frustrate passengers and reduce service quality. Intelligent traffic management systems, optimized scheduling, and noise mitigation strategies can improve ride experience and reduce congestion. From a technical perspective, factors like car vibration, leveling accuracy, and door operation efficiency are essential for safety and reliability. Predictive maintenance using vibration analysis and acoustic monitoring can prevent failures and enhance long-term performance. Meanwhile, design considerations such as space planning, lighting, ventilation, and aesthetic appeal influence passenger comfort, making well-designed elevators not only efficient but also more user-friendly.

Future research should explore the relationship between operation, technical performance, and design in shaping user satisfaction. While these aspects are often studied independently, a comprehensive approach is needed to understand how they interact. For example, improving operational efficiency through traffic control might enhance ride comfort, but poor technical maintenance could still lead to negative experiences. Similarly, integrating smart maintenance systems with well-planned elevator design could improve both safety and passenger perception. A user satisfaction model that evaluates these three dimensions holistically could provide valuable insights for developers, engineers, and policymakers to create high-performance, user-centric elevator systems in modern high-rise buildings.

This paper reviewed the operational, technical, and design dimensions of elevator systems, demonstrating their individual and combined impact on user satisfaction in high-rise residential buildings. The findings show that while each factor has been studied to some extent, comprehensive studies that integrate all three are rare. This review contributes a thematic synthesis that supports a more holistic understanding of elevator performance.

Future research should explore the interconnection between operational efficiency, technical performance, and design choices, and how these jointly shape user experiences. Such multidisciplinary inquiry is essential for developing smarter, more user-centric elevator systems in urban residential environments.

V. ACKNOWLEDGEMENT

The main author would like to express sincere gratitude to the Building Surveying Department of UiTM Perak Branch, for support throughout this research. Additionally, heartfelt thanks go to family, friends, and colleagues for their unwavering encouragement and motivation during this academic journey. Their continuous support has been a source of strength and perseverance.

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ASSESSING ACCEPTANCE OF RETIREMENT VILLAGES IN KLANG VALLEY, MALAYSIA: STRATEGIES TO OVERCOME BARRIERS

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ABSTRACT

Malaysia's aging population has increased demand for alternative senior housing, such as retirement villages (RVs), which promote independence, security, and social engagement. While RVs are well-studied in Western countries, acceptance in Malaysia remains unclear, highlighting the need for further research. This study examines RVs in Klang Valley by assessing (i) acceptance level, (ii) key barriers, and (iii) strategies to enhance acceptance. Literature revealed RV acceptance is generally higher in Western than Asian countries. Five key barriers—cultural, social, financial, legal, and living environment—were identified, along with four key strategic for acceptance improvement. A quantitative approach will be used, distributing structured questionnaires to individuals aged 30+ nearing retirement or involved in elder care decisions. Data collected will be analyzed using Arithmetic Mean, Mann-Whitney U, Kruskal-Wallis, and Spearman's Correlation. Findings will offer insights into Malaysians' RV acceptance, highlight barriers hindering acceptance, and propose strategies to increase acceptance. Results obtained will be guiding policymakers and stakeholders in improving elder care infrastructure and promoting RVs as a viable retirement option which aligned with Malaysia Madani under Housing for the Rakyat.

Keywords: retirement villages, acceptance, barriers, strategies, ageing population

I. INTRODUCTION

Malaysia is experiencing a demographic shift towards an ageing society, with the population aged 65 and above expected to rise from 7.9% in 2010 to 15% by 2030 and 16.3% by 2040 (Ramli & Nazir Kamaludin, 2021). This trend increases the demand for senior housing, emphasizing safety, socialization, and healthcare services. In response, initiatives like the 12th Malaysia Plan (12MP) and the Madani Inclusive Housing Project promote retirement villages (RVs) to address elderly care needs (Ibrahim, 2023). However, challenges such as insufficient elderly care facilities and unregulated services persist (Robert et al., 2019).

RVs offer a viable housing solution, promoting independence, security, and well-being among seniors. Unlike nursing homes, they focus on active ageing while addressing social isolation and financial concerns (Lim et al., 2022). While RVs are well-established in Western countries, they are often government-run and stigmatized in Asian societies (Leartbuasin & Potisarattana, 2015). In Malaysia, filial piety traditionally places elder care within families, but economic shifts and social mobility have led to more "empty nesters," increasing interest in RVs (Li & Wu, 2022). However, awareness and infrastructure remain limited. This research explores RVs as a response to Malaysia's ageing demographic, examining acceptance, barriers, and strategies for wider adoption.

a. *Problem Statement*

Studies on RVs have been more extensive in Western countries than in Asia, highlighting differences in research focus. In Australia, Malta et al. (2018) examined resident experiences and conflicts, while Gilbert et al. (2024) explored RV living during the COVID-19 pandemic. Similarly, Bloomfield et al. (2023) in New Zealand analyzed post-relocation trends. In Malaysia, RV research remains in its early stages, focusing on Islamic RV concepts (Ismail et al., 2021), relocation factors (Chaulagain et al., 2021), and generational preferences (Ismail et al., 2023). However, Malaysia is a country profoundly influenced by Asian culture and society, research related to concept of RVs in Malaysia is still in the introductory phase compared to that in Western countries

(Julaihi et al., 2022). While Malaysia faces an aging population, most existing studies emphasize RV concepts rather than acceptance level. Hence, this study aims to bridge this gap by assessing Malaysians' acceptance of RVs, identifying barriers, and proposing strategies to guide policymakers in enhancing elder care and RV development.

b. *Research Aim and Objectives*

This research aims to uncover the concept of retirement villages in Malaysia. Thus, to achieve the aforementioned research aim, the following research objectives are formulated.

i. To evaluate the level of acceptance on the concept of retirement villages.
ii. To analyse the barriers that hinder the acceptance of retirement villages.
iii. To propose relevant strategies for enhancing the acceptance of retirement villages.

c. *Scope of Research*

This study is conducted in Klang Valley, Malaysia, focusing on individuals aged 30 and above who are nearing retirement or involved in elder care decisions.

II. LITERATURE REVIEW

The concept of RVs has gained attention due to the rapid growth of the ageing population in Malaysia, leading to increased demand for elderly healthcare, lifestyle services, and specialized housing. RVs, also known as continuing care retirement communities, provide a combination of independent living, medical support, and communal activities for individuals aged 55 and above (Julaihi et al., 2022). Unlike traditional elderly care facilities, RVs are privately managed, offering modern living spaces with tailored services and amenities to enhance seniors' quality of life. These communities typically feature facilities such as community halls, fitness centers, swimming pools, libraries, and medical clinics to promote social interaction, and independence (Xia et al., 2015). While well-established in Western countries (Sufian & Mohamad, 2013), RVs in Malaysia are still emerging, resembling the local Pondok system, which integrates religious education with elderly care (Peri et al., 2020). Compared to elderly care institutions under the Care Centres Act 1993 (Abdul Mutalib & Alias, 2021), RVs provide a holistic living experience that combines housing, medical services, and social engagement. As awareness grows, RVs are expected to become a more attractive option for seniors seeking security and independence.

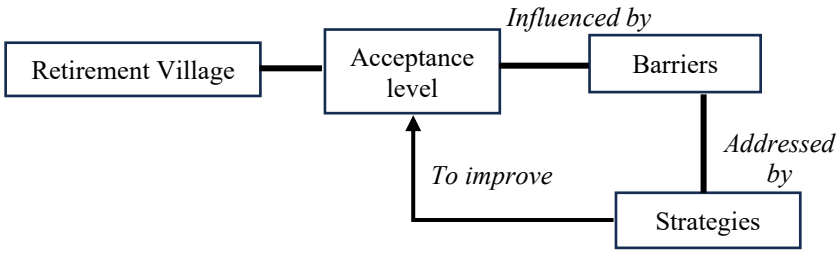


Figure 1.0 Research Conceptual Framework

Figure 1.0 presents the research conceptual framework, illustrating the barriers influencing the acceptance level of RVs. The acceptance level of RVs is influenced by various barriers that potential RV's occupants perceive. By identifying the specific barriers faced by each group, targeted strategies can be developed to address these issues effectively. Thus, understanding the relationship between the perceived barriers and the strategies to overcome them is essential to increasing the acceptance of RVs. The implementation of these strategies should aim to mitigate barriers, thereby fostering a more positive view of RVs and ultimately improving their acceptance levels across various demographic groups.

Acceptance

The acceptance of RVs in Malaysia remains limited due to cultural, economic, and societal factors. Unlike Western countries, where individualism and financial independence influence retirement planning (Liu et al., 2016), Malaysian society places strong emphasis on filial piety and collectivist values, expecting children to care for aging parents. As a result, senior congregate living is often seen as a last resort rather than a preferred choice. However, RVs are gradually emerging, with facilities like Green Acres, The Green Leaf, Eden-on-the-Park, and Millennia Village offering independent living with care services. Additionally, Muslim-oriented retirement facilities such as Pondok Warga Emas integrate Islamic values with communal living (Abdul Mutalib & Alias,

2021). Affordability remains a concern, though Malaysian RVs tend to be more cost-effective than Western models. The lack of regulatory frameworks further slows acceptance, creating uncertainty about quality and sustainability. Despite these challenges, urbanization, changing family dynamics, and growing awareness of RV benefits may drive greater acceptance, shifting acceptance towards alternative senior living options (Julaihi et al., 2022).

I. Barriers that Hinder the Acceptance of Retirement Villages

The acceptance levels of RVs are affected by several barriers which can be categorized into cultural, social, financial, legal, and living environment aspects.

Cultural

Culture significantly influences the acceptance of RVs in Malaysia, where traditional family values emphasize filial piety and multigenerational living, making institutionalized elderly care less desirable. RVs are often associated with abandonment, leading to social stigma and concerns over family reputation (Julaihi et al., 2022). Additionally, religious and cultural considerations shape retirees' preferences, as they seek environments that accommodate their beliefs, dietary needs, and prayer facilities (Ismail & Zamry, 2020). Language barriers further challenge RV acceptance, as Malaysia's multilingual society creates communication difficulties between retirees and staff, affecting trust and service accessibility (Ibrahim et al., 2018).

Social

Misconceptions and limited awareness hinder RV acceptance in Malaysia, as many equate them with nursing homes, fearing loss of independence and social connections (Samsudin et al., 2023). Additionally, concerns about isolation and loneliness deter seniors from considering RVs, as they worry about being separated from family and traditional support networks ((Lim et al., 2022). The fear of losing independence also plays a crucial role, as some elderly individuals perceive RVs as restrictive environments that may limit their autonomy and lifestyle choices (Hu et al., 2017).

Financial

Inadequate retirement financial planning and limited Employees Provident Fund (EPF) savings make RVs less affordable for many retirees, leading them to prefer living with family to reduce financial strain (Ramli & Mohamad Shariff, 2023). Affordability remains a major issue, as high entry fees and unclear cost structures make RVs seem exclusive to wealthier individuals (Liu et al., 2018). Additionally, the "sandwich generation" faces financial constraints, balancing the costs of supporting both elderly parents and their own children, which limits their ability to afford RVs (Chen & Zhou, 2022). Economic uncertainty and inflation further strain retirees' savings, making long-term financial commitments like RVs less feasible. Moreover, rigid payment structures, including high upfront fees and deferred management costs, reduce affordability, as flexible installment plans are rarely available (Hu et al.2017).

Legal

Legal barriers to RV acceptance in Malaysia stem from unclear regulations and insufficient government support. The absence of a well-defined regulatory framework creates uncertainty for potential residents and investors, as seen in cases like Green Acres in Ipoh, where lifetime lease models lack clear guidelines on deposit returns and legal protections (Samsudin et al., 2023). Additionally, inadequate government policies hinder RV development and affordability, with limited initiatives to promote age-friendly communities or financial support, unlike models in the UK and Australia (Hu et al., 2017).

Living Environment

Accessibility, safety, and social spaces are key environmental factors influencing RV acceptance, with older adults preferring well-connected locations that offer healthcare, family support, and transportation (Mulliner et al., 2020). Safety is another major factor, as high crime rates and poor infrastructure can negatively affect the mental and physical well-being of residents, reducing the desirability of RVs (Tan, 2022). Additionally, inadequate facilities, such as unreliable utilities and the lack of recreational and medical services, may lead to dissatisfaction and social isolation among residents. The availability of healthcare support is also critical, as

many older adults expect caregiving assistance in RVs, but management policies often fail to meet these expectations (Broad et al., 2020). Furthermore, poor environmental quality, including air and noise pollution, can impact residents' cognitive health and overall comfort (Lo et al., 2019).

II. Strategies to Enhance the Acceptance of Retirement Villages

To improve the acceptance of RVs in Malaysia and overcome barriers, a multifaceted strategy is needed. This includes enhancing approaches in cultural and social understanding, financial affordability, legal inclusivity, and the quality of the living environment.

Cultural and Social

Cultural and social strategies in RVs enhance engagement and inclusivity by integrating religious and cultural practices, such as halal food and prayer spaces, to meet Malaysian seniors' needs (Ismail & Zamry, 2020). Social engagement through community activities and mentorship programs strengthens social sustainability, reducing isolation and enhancing well-being. Additionally, addressing stigma through educational programs and open house events helps reshape perceptions of RVs as vibrant communities rather than mere elderly homes (Chaulagain, et al., 2021). Family involvement through flexible visiting policies and family-friendly events further improves acceptance and resident satisfaction (Hu et al., 2018). Lastly, public awareness campaigns highlighting RV benefits, financial aid options, and lifestyle amenities can increase acceptance and encourage wider adoption (Abdul Mutalib & Alias, 2021).

Financial

Financial strategies for RVs emphasize affordability, transparent pricing, and financial planning support to help seniors manage expenses and recognize the long-term benefits of RV living. Flexible payment options, including rent, lease, and purchase models, cater to diverse financial needs and improve accessibility (Chaulagain et al., 2021). A tiered pricing structure allows seniors to choose housing based on their financial capacity, promoting inclusivity (Hu et al., 2020). Transparent cost structures, detailing fees and financial obligations, foster trust and confidence among potential residents. Furthermore, highlighting cost efficiencies, such as savings on maintenance and utilities compared to private homes, strengthens the financial appeal of RVs (Bohari et al., 2024).

Legal

Legal strategies in RVs focus on enforcing regulations to protect residents' rights, maintain living standards, and establish a clear framework for land status, building specifications, and lease models in Malaysia (Abdul Mutalib & Alias, 2021). Additionally, government support, such as Malaysia’s National Policy for Older Persons, has contributed to RV development by promoting age-friendly environments, similar to policies in Australia and the UK (Bohari et al., 2024). Public-private partnerships (PPPs) further enhance affordability and accessibility, with Malaysia’s Ministry of Housing and Local Government introducing PPP models to provide affordable RV units through rental schemes (Samsudin et al., 2023).

Living Environmental

Living environment strategies in RVs focus on accessibility, quality services, and sustainability, with strategic locations near healthcare, shopping, and public transport enhancing convenience and independence (Hu et al., 2018). Universal design features like ramps, grab rails, and accessible transport comply with Malaysia’s MS 1184:2014 guidelines, promoting safety and mobility (Shahril & Zahari, 2023). Furthermore, high-standard services, including healthcare, wellness programs, and social activities, foster a vibrant community. While sustainable features such as green spaces, energy-efficient systems, and waste management can improve affordability and well-being (Zuo et al., 2014). Lastly, professional management with trained staff ensures quality care, making RVs a more attractive option for seniors (Losekoot & Theresa, 2018).

Summary of Findings from Literature Review

Table 1.0 illustrates a summary of the findings from the literature review. Firstly, this research aims to determine

the acceptance level of RVs in Malaysia. The acceptance levels are hindered by different barriers which can be classified into cultural, social, financial, legal aspects, along with the living environment. To overcome these barriers and improve acceptance level, this research identified several strategies that can be categorised into cultural and social, financial, legal, and living environment.

Table 1.0 Summary of Findings from Literature Review

Acceptance Level: Retirement Villages	Barriers	Strategies
Cultural	1. Traditional Family Values and Perceptions 2. Cultural and Religious Concerns 3. Language Barriers and Communication Issues	1. Integrating Cultural Practices 2. Social Support and Community Engagement 3. Addressing Stigma and Misconceptions 4. Family-Inclusive Policies 5. Public Awareness Campaigns
Social	1. Lack of Awareness and Understanding 2. Isolation and Loneliness 3. Losing Independence	
Financial	1. Lack of Retirement Financial Planning 2. Affordability Concerns 3. Family Financial Constraint 4. Economic Uncertainty 5. Lack of Flexible Payment Options	1. Financial Planning Support and Incentives 2. Flexible Payment and Ownership Plans 3. Different Pricing Tiers 4. Transparent Cost Structures 5. Optimizing Cost Efficiency and Value
Legal	1. Unclear Regulatory Framework 2. Insufficient Government Involvement and Policy Support	1. Comprehensive Legal Framework 2. Leverage Government Support and Policy 3. Public-Private Partnerships
Living Environment	1. Impact of Location and Accessibility 2. Inadequate Facilities 3. Healthcare Support Concerns 4. Poor Management and Staffing 5. Poor Environmental Quality	1. Optimal Location and Accessibility 2. Enhancing Accessibility and Design Standards 3. High-Standard Services and Facilities 4. Professional Management and Adequate Staffing 5. Enhance Environmental Sustainability

III. RESEARCH METHODOLOGY

This study adopts a quantitative approach to ensure objective, measurable, and generalisable findings on RV acceptance in Klang Valley. A questionnaire survey is used for data collection from a broad sample. This method allows for structured analysis, trend identification, and correlation assessment, making it the most effective approach for evaluating acceptance levels and influencing factors.

A. Questionnaire Design

The questionnaire will be structured into four sections to align with the research objectives. A brief definition of "Retirement Village" will be provided at the start for clarity. Section A will be designed to collect demographic details such as age, gender, marital status, ethnicity, income, and education. Section B assesses respondents' acceptance of RVs in Klang Valley. Sections C and D will be examined the five barriers to RV acceptance and four strategies to improve it, using a five-point Likert scale from Strongly Disagree to Strongly Agree.

B. Sampling Size and Technique

This study will require a total of 374 participants determined with Cochran's formula on sample size calculation:

$$n = \frac{Z^2 p(1-p)}{e^2}$$

$$n = \frac{1.96^2(0.5808)(1-0.5)}{0.05^2} = 374$$

The above calculation is based on the following assumption:

i. Level of confidence = 95% (Therefore, Z = 1.96)
ii. Margin of error (e) = 5% or 0.05
iii. The proportion of the population with attributes understudy, therefore (p) = (5,477,400/9,430,900) = 0.5808

According to the Department of Statistics Malaysia (2024), there are 5,477,400 individuals aged 30 and above in Selangor and WPKL, out of a total population of 9,430,900. Based on Cochran's formula, the sample size for this study will be 374 individuals. To recruit participants, this study will use convenience sampling by gathering data from readily available individuals in public spaces and through personal networks. Additionally, snowball sampling will be employed, where initial respondents will refer others who meet the study criteria. This combined approach ensures efficient recruitment while reaching a diverse range of participants aged 30 and above in Klang Valley.

IV. PROPOSED DATA ANALYSIS

The data collected will be analyzed using IBM Statistical Package for the Social Sciences (SPSS) software for both descriptive and inferential statistical analysis, employing four statistical tests: Arithmetic Mean, Mann-Whitney U Test, Kruskal-Wallis Test, and Spearman's Correlation Test. The Arithmetic Mean Test will be used to determine the average acceptance levels, identify major barriers, and assess the effectiveness of strategies, providing valuable insights into RV acceptance in Klang Valley and informing strategies to improve their feasibility in Malaysia. The Mann-Whitney U Test will compare differences in RV acceptance based on demographic factors such as gender, where the dependent variables are the 'barriers influencing the acceptance level of RVs' and the 'strategies that enhance the acceptance level of RVs.' The Kruskal-Wallis Test will further examine variations in RV acceptance across multiple independent variables such as age, marital status, ethnicity, education level, household income, and occupation, with barriers and strategies serving as the dependent variables. Lastly, Spearman's Correlation Test will be conducted to assess the relationship between the barriers affecting RV acceptance and the strategies aimed at enhancing acceptance in Klang Valley, Malaysia. This comprehensive statistical approach systematically describes, evaluates, and establishes relationships within the data, ensuring meaningful and reliable survey results.

CONCLUSION AND RECOMMENDATION

In a nutshell, this study provides valuable insights into the acceptance of retirement villages (RVs) in Klang Valley, Malaysia, aligning with the Malaysia Madani vision, particularly under Housing for the Rakyat, which emphasizes inclusive, affordable, and sustainable housing solutions. By examining the cultural, social, financial, legal, and environmental barriers affecting RV acceptance, this research helps policymakers develop supportive regulations and incentives to promote RV development while ensuring affordability and accessibility for Malaysia's aging population. It also benefits the industry by guiding developers in designing cost-effective and culturally suitable RV models, while financial institutions and elder care organizations can use these findings to create tailored financing schemes and support services. Furthermore, this study highlights the social and emotional aspects of RV living, addressing stigma and promoting community engagement to enhance the quality of life for seniors. For academia, it provides a foundation for future research on aging trends, elder care policies, and innovative housing solutions. Ultimately, this study supports Malaysia Madani's commitment to sustainable and community-driven elder care, ensuring that the nation is well-prepared to accommodate its aging population with dignity and security.

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QUANTITY SURVEYOR ROLE IN GREEN PROPERTY DEVELOPMENT TOWARDS ESG IN MALAYSIA

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ABSTRACT

Green building practices are rapidly developing worldwide, yet the role of Quantity Surveyors in implementing Environmental, Social, and Governance (ESG) principles in green property development remains insufficiently explored in Malaysia. Despite the global advancements in integrating green technologies, energy-efficient systems, and sustainable materials, the tasks and responsibilities of QS professionals in Malaysia for green development have not been fully understood. Additionally, the lack of comprehensive local ESG standards, coupled with limited awareness among industry stakeholders, poses a significant knowledge gap. This study aims to address these gaps by examining the evolving role of QS professionals in promoting and executing ESG driven green property development in Malaysia. The objectives are to critically review and synthesize the latest ESG related policies, standards, and guidelines relevant to green property development in Malaysia, explore the specific tasks of QSs in green property development globally, and develop an ESG framework for QS practices in the Malaysian context. The study will employ a mixed-method approach, including literature reviews, policy analysis, surveys, and interviews with industry stakeholders. The findings will provide critical insights into how QS can facilitate environmentally responsible, socially inclusive, and ethically governed construction projects, thereby strengthening the sustainability practice of Malaysia's property development sector.

Keywords: Quantity Surveyor, Green Property Development, ESG Framework, Malaysia

I. INTRODUCTION

The construction industry has undergone big changes, evolving from basic structural practices to sophisticated, environmentally sustainable developments. This transformation is not only driven by technological advancements but also by an urgent need to address climate change, resource depletion, and social responsibility. As environmental, social, and governance (ESG) concerns become central to national and global development agendas, the construction sector faces increasing pressure to deliver projects that balance economic feasibility with sustainable practices. In this context, green property development has become an important approach, emphasizing energy efficiency, sustainable materials, and waste reduction, while also promoting social equity and economic resilience. Certification systems such as LEED and BREEAM have guided this shift, but in Malaysia, recent regulatory updates, government incentives, and ESG reporting mandates have reshaped how sustainability is integrated into construction practices. From these changes, the role of Quantity Surveyors (QS) has expanded beyond traditional cost and contract management to encompass ESG-driven responsibilities. However, existing literature largely focuses on the general functions of QS in sustainable construction, lacking depth in how their roles are adapting to Malaysia's evolving ESG framework. This study addresses this gap by examining how Malaysian QS professionals are responding to contemporary ESG imperatives in cost management, procurement strategies, and project execution. It also explores the challenges they face and the innovations they are adopting to remain competitive and compliant. In doing so, the research highlights the critical role of QS in translating ESG objectives into measurable outcomes, offering timely insights for both industry practitioners and policymakers.

II. METHODOLOGY

This study adopts a mixed-methods design, combining exploratory and descriptive approaches to examine how QS in Malaysia integrate ESG principles into green property development. The research is carried out in three phases. Phase one involves a comprehensive review of recent ESG-related policies, industry standards, and academic literature to identify current trends and establish a relevant conceptual framework. This ensures the study reflects recent developments in Malaysia's ESG trend .In phase two, semi-structured interviews with key stakeholders including QS professionals, developers, policymakers, and sustainability experts will explore challenges and practices in ESG adoption. A quantitative online survey, pre-tested for reliability, will be distributed to a broader group of construction professionals to validate findings and assess industry-wide trends. Phase three focuses on developing a context-specific ESG framework for QS practice, based on the combined insights from both qualitative and quantitative data. The target population includes professionals involved in green construction in Malaysia, with a survey sample of 200 participants selected using the Krejci and Morgan method, and interviewees chosen via purposive sampling. Data will be analysed using thematic analysis for qualitative inputs and descriptive statistics for survey responses. Triangulation, instrument pre-testing, and member checking will be applied to enhance validity and reliability. While limitations such as sample bias and rapid ESG changes may arise, the study is designed to provide timely, practical insights into QS contributions to ESG in Malaysia's construction industry.

III. LITERATURE REVIEW

In Malaysia, several frameworks have been implemented to promote sustainable development, including the Economic Transformation Programme, Government Transformation Programme, and the 10th Malaysian Plan. The government green procurement concept encourages eco-friendly public sector purchasing to reduce environmental impacts and boost the economy. The National Green Technology Policy promotes green technology adoption, with five strategic thrusts focusing on institutional frameworks, green tech innovation, human capital, and public awareness. The Green Technology Financing Scheme allocated RM1.5 billion from 2010-2012 and RM2 billion from 2013-2015 to support green projects. Additionally, initiatives like the Small Renewable Energy Power Program and the Green Building Index emphasize renewable energy and the green economy, supporting Malaysia's sustainable future (Norhamiza, 2024).

Hence, from the engagement of the government in green development, the role of the Quantity Surveyor should be up to date. This role of Quantity Surveyors in the context of green property development with a specific focus on integrating Environmental, Social, and Governance principles must be extremely focused. The findings indicate that the role of QSs has significantly expanded beyond traditional cost management to include responsibilities related to sustainability, resource efficiency, and long-term environmental stewardship. Quantity Surveyors are now significant in ensuring that sustainable practices, such as energy-efficient technologies, eco-friendly materials, and green certifications, are incorporated into the financial and managerial aspects of construction projects (Qian Shi, 2013). This reflects the growing importance of balancing financial considerations with environmental and social factors.

A comparison between the role of QSs in conventional versus green property development highlights a notable shift in responsibilities. While traditional property development largely focuses on immediate construction costs, green property development demands a more comprehensive approach that accounts for both the high initial costs of sustainable materials and systems and their long-term operational savings. As researcher highlights, green certifications such as LEED or BREEAM require QSs to assess and manage the procurement of sustainable materials and technologies that align with these certification standards. (Sara, 2008) Moreover, QSs are involved in lifecycle costing, which helps evaluate the environmental and operational impact of building systems over their lifespan, ensuring that green buildings are financially viable while fulfilling sustainability goals.

The integration of ESG principles into construction projects is another important finding of this paper. Quantity Surveyors play a crucial role in aligning projects with these principles, which emphasize the reduction of environmental impact, social responsibility, and good governance practices. According to (C.K. Yap, 2024), the environmental component of ESG is particularly significant, as QSs are tasked with recommending and controlling the cost of within the budget while incorporate energy-efficient systems, sustainable materials, and waste management practices that contribute to green building standards. The social aspect of ESG, which focuses on promoting community engagement, fair labour practices, and social equity, is also addressed by QSs, who ensure that these principles are embedded in the procurement and construction processes. Finally, governance is an integral part of the QS's role, as they help ensure compliance with regulatory frameworks, oversee financial risk management, and enforce ethical procurement practices.

The case studies examined in this study, such as the Tun Razak Exchange (TRX), Bukit Bintang City Centre (BBCC), and Bandar Rimbayu Township, demonstrate the practical application of QS expertise in green property developments. These projects have achieved various levels of green certifications and serve as examples of how QSs are integral in managing both the financial and sustainability aspects of such developments. As seen in the TRX project, a Platinum-rated green building, QSs played a key role in balancing the initial capital investment in sustainable technologies with the expected long-term operational savings, ensuring both financial and environmental goals were achieved. Similarly, for the BBCC and Bandar Rimbayu Township projects, QSs were responsible for managing the financial aspects of energy-efficient designs, sustainable material selection, and green procurement, ensuring the successful integration of sustainability into these developments. (Star, 2022)

Looking ahead, the future of Quantity Surveying in green property development appears promising, with an increasing demand for eco-friendly buildings and the widespread adoption of ESG principles. As the construction industry moving forward sustainability, the role of QSs will become even more essential in ensuring that projects are both financially viable and aligned with global sustainability standards. The future responsibilities of QSs will likely expand further to include a more proactive role in the early stages of green property development, particularly in conducting feasibility studies and providing clients with comprehensive analyses of the financial and environmental implications of green technologies (Sara, 2008). Furthermore, as ESG frameworks become more integral to the construction process, QSs will be instrumental in guiding projects through the certification processes, ensuring compliance with both local and international sustainability standards.

Based on the discussion above, a general mapping of basic and supplementary services has been developed to illustrate the connection between ESG factors and the roles of QS in Malaysia. However, this mapping also reveals several challenges faced by industry stakeholders in effectively incorporating ESG principles into QS services. Understanding these challenges is essential for developing a practical framework that supports the integration of ESG in green property development.

Table 1.0 Challenges Faced by Quantity Surveyor Services toward ESG in Malaysia

Scope of QS Services	ESG Pillar	Challenges Faced
Basic Services	Environmental	**Limited availability of reliable cost data for sustainable materials and technologies** makes it difficult for QSs to provide accurate estimates. Additionally, **lack of standard ESG guidelines in procurement** complicates the selection of eco-friendly suppliers and contractors.
	Social	**Balancing project budgets with social goals**, such as community benefits and inclusive design, poses a challenge. Stakeholders often face **pressure to deliver cost-efficient solutions,** which may sideliner social priorities.
	Governance	**Ensuring transparency and compliance** in procurement and reporting is hindered by **inconsistent regulatory enforcement** and **varying levels of ethical awareness** among project teams.
Supplementary Services	Environmental	Lifecycle costing while valuable, is **underutilized due to limited expertise and tools**. Evaluating long-term environmental costs is challenging in the absence of **clear benchmarks or data.**
	Social	Measuring social impacts requires **engagement with communities and stakeholders**, which is often constrained by **time, budget, and lack of standardized assessment frameworks.**
	Governance	Auditing and governance functions are often viewed as secondary responsibilities. **Resistance to**

		transparency and **lack of ESG integration in traditional project management systems** limit the effectiveness of governance oversight.

In conclusion, while Quantity Surveyors play a pivotal role in supporting ESG integration in green property development, industry stakeholders face several systemic and practical challenges. These include data gaps, regulatory inconsistencies, competing priorities, and limited ESG-specific training. To overcome these barriers, the construction industry must adopt clearer standards, provide ESG training, and foster a culture of accountability and sustainability. Addressing these challenges will empower QSs and other stakeholders to bridge the gap between environmental, social, and financial performance in Malaysia's built environment.

IV. KEY ELEMENTS OF GREEN QUANTITY SURVEYING

As the demand for sustainable buildings increases globally, Green Quantity Surveying (GQS) has become essential in the construction and real estate industries. Modern QSs must adapt by developing new skills to meet the challenges posed by green building practices and align with ESG frameworks (Mbachu, 2015). GQSs now integrate environmental, social, and financial considerations into cost planning and analysis, expanding beyond traditional cost management.

Green Costing
Green building design requires a revaluation of cost structures. QSs must understand green technologies and factor in the additional costs for green building certifications like LEED, BREEAM, or WELL. Green QSs must balance sustainable technology investments with long-term savings while managing client expectations.

Carbon Footprint Management and Green Costing
GQSs help manage a building's carbon footprint by measuring both embodied and operational carbon emissions. This includes integrating carbon metrics into the overall cost plan, allowing building owners to minimize their footprint and achieve sustainability goals. QSs also advise on carbon credits and green initiatives (UNEP, 2011).

Life Cycle Costing and Environmental Assessment
Life Cycle Costing (LCC) evaluates a building's total cost over its lifetime, including both construction and operational expenses. It helps quantify long-term savings from sustainable technologies. Life Cycle Assessment (LCA) further analyses environmental impacts across the building's lifecycle, and Green QSs integrate both LCC and LCA into cost models to guide sustainable decisions (Brenda, 2014).

V. QUANTITY SURVEYOR ROLE IN GREEN PROPERTY DEVELOPMENT

Green Property Development focuses on reducing environmental impacts while promoting sustainability. QSs ensure green principles are integrated throughout the project by assessing the financial viability of green technologies and materials, preparing cost estimates, managing life-cycle costs, and supporting green procurement. They also play a role in Lean Construction (LC), which optimizes resource use and minimizes waste (Mohd Arif, 2013). QSs support every stage of the project, from cost estimation to project management, ensuring both financial feasibility and sustainability goals are met (Qian Shi, 2013; Sara, 2008).

However, current QS practices and existing standards, such as the Standard Method of Measurement (SMM) in Malaysia, do not adequately integrate ESG considerations. Conventional cost management largely focuses on upfront costs and efficiency, with limited attention to sustainability unless externally mandated.

This research proposes the development of an enhanced Standard of Measurement for Malaysia that explicitly incorporates ESG aligned practices. It will address areas such as:

Sustainable Cost Estimation
Incorporates the full life-cycle cost of green buildings, not just initial expenses. This ensures that long-term savings from energy, water, and maintenance efficiencies are reflected in cost planning, making sustainability financially justifiable.

Green Procurement Guidelines
Adds sustainability criteria to contractor and material selection processes. QS will prioritize vendors and contractors who use eco-friendly materials, energy-efficient systems, and environmentally responsible practices.

ESG Risk Assessment
Evaluates risks related to the performance and financial implications of green systems. This includes uncertainties in the durability, cost, and ROI of sustainable technologies, ensuring project decisions are informed and resilient.

Material and Waste Management Standards
Promotes use of low-impact materials and structured waste reduction methods. QSs will follow guidelines to select recycled, locally sourced, or low-carbon materials and apply LC techniques to reduce waste throughout the project.

Governance Requirements
Ensures transparency, accountability, and ethical compliance in all QS services. This includes clear reporting, adherence to green regulations, and ethical procurement to meet both local laws and international ESG standards.

Through a comparative analysis of traditional and green QS roles, this study highlights the gaps in current standards and underscores the need for a dedicated ESG-integrated framework. The proposed SMM concept will serve as a guideline to align QS services with sustainability goals, ensuring that Malaysia's construction sector can meet global expectations for environmental responsibility and long-term value creation.

ACKNOWLEDGEMENT

Deeply appreciate the invaluable guidance, support, and feedback from all those who have contributed to this paper, including Department of Quantity Surveying UM, friends, and family. Their encouragement, expertise, and unwavering belief have been essential in shaping and completing this paper.

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THE LIMITATIONS OF MALAYSIA STRATA LAW IN GOVERNING RENT-TO-OWN STRATA SCHEMES

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ABSTRACT

The Rent-to-Own (RTO) scheme in Malaysia aims to improve housing affordability by allowing tenants to transition into homeownership over time. However, Malaysia's existing strata laws, governed by the Strata Titles Act 1985 and the Strata Management Act 2013, do not adequately address the legal complexities of RTO strata schemes. This study investigates the limitations of Malaysia's strata laws in governing RTO strata schemes, focusing on ownership status, strata title registration, management corporation formation, and occupiers' legal rights. A qualitative research approach was adopted, utilizing legal document analysis and comparative case studies from New South Wales, Australia. Findings reveal key legal ambiguities, including the lack of recognition for RTO occupiers, delays in strata title registration, exclusion from management governance, and restricted legal rights. Comparisons with Australia highlight the need for structured legal provisions to protect RTO occupiers and integrate them into the strata management system. To address these issues, the study recommends legal reforms, such as recognizing RTO occupiers as stakeholders, mandating timely title registration, and allowing gradual inclusion in management corporations. These findings contribute to the discourse on housing affordability and legal governance, offering policy recommendations to enhance Malaysia's strata law framework for better RTO integration.

Keywords: Rent-to-Own (RTO); housing affordability; strata title; strata management

I. INTRODUCTION

The Rent-to-Own (RTO) scheme is a financing model designated to enhance housing affordability, particularly for low- to middle-income groups who struggle to secure traditional mortgage loans. In Malaysia, several RTO schemes have been introduced by financial institutions and government agencies to mitigate the rising cost of homeownership. However, a critical gap exists in Malaysia's strata law framework, which lacks clear provisions governing RTO strata schemes. The Malaysian strata ownership system is primarily regulated under the Strata Titles Act 1985 (Act 318) and the Strata Management Act 2013 (Act 757), both of which focus on traditional ownership models. The absence of specific legal frameworks for RTO schemes raises uncertainties regarding tenant's rights, strata title registration, governance structures, and legal protections for RTO occupiers. This paper investigates the limitations of Malaysia's strata laws in governing RTO schemes, identifying key legal uncertainties and governance challenges. The objective is to analyze the shortcomings in the current legal framework and provide recommendations to address these issues within the existing strata law structure. This research is based on a review of past studies and secondary sources, focusing on strata laws in Malaysia and New South Wales (NSW), Australia. To analyse the legal frameworks, content analysis is used to examine relevant legal provisions in both countries. A comparative analysis then highlights the differences in how each system handles RTO schemes, offering insights into possible improvements for Malaysia. This paper begins by explaining how RTO schemes operate in Malaysia, followed by an overview of the country's strata scheme framework. It then explores the relevant strata laws that apply to RTO strata schemes, highlights key limitations within the Malaysian strata laws, and concludes with a comparative analysis of RTO strata schemes in New South Wales, Australia and Malaysia.

II. RENT-TO-OWN (RTO) SCHEMES IN MALAYSIA

Rent-to-Own schemes have been developed to address the issue of housing affordability and ownership for low-income groups (The Sun, 2020). It is one of the cooperations between the Ministry of Local Government Development (KPKT) and financial institutions in providing attractive and sustainable housing financing packages (Bernama, 2023). This scheme is for those who are unable to own a house through traditional financing, which allows them to own a property through renting within a certain time agreed and purchase the property later once the rental tenure matures or they have good finances to secure a mortgage loan (Aziz, Tenku Fazil, Jiram, & Abdul Jalil, 2019).

The Maybank Group formally introduced the RTO scheme called HouzKEY in 2018 in order to provide a financing plan that is appropriate for middle-class group homeowners. Maybank partnered with five prominent developers in Malaysia to offer RTO schemes in Kuala Lumpur and Selangor (Kay, 2017). The RTO occupier would only need to pay monthly rental without any down payment through Maybank HouzKEY (Aziz et al., 2019). Through HouzKEY, homebuyers begin with a five-year term (referred to as the "Initial Tenure") and are then free to extend for a maximum of thirty more years (Maybank2own, n.d.).

Based on the 12th Malaysia Plan (2021), the RTO program will now include homes up to RM500,000 with the opportunity to buy within five years of renting. Furthermore, the first home will continue to be financed under the Fund for Affordable Homes and Youth Housing Scheme. It aligns with the current market prices and allows first-time homebuyers to enjoy a great living in their first house.

The RTO Scheme is for property that will be rented for between five (5) to ten (10) years, which is the temporary period after signing a contract of leasing and purchase agreement with the developer. The RTO occupier would have a lot of time to consider whether to purchase and transfer the ownership from renting to purchasing or not from the bank and developers (Pen Nei, Mohd Tobi and Jasimin, 2023). If the RTO occupier decides not to purchase the property after the rental period, the valuation sectors need to value the property's market value and rental rate that is feasible to new purchasers (EcoWorld, 2019).

Maybank Group collaborated with EcoWorld in realizing the dreams of their customers who want to own a house by developing a great RTO scheme concept with great key elements to improve the confidence of their customers in becoming homeowners in the future (EcoWorld, 2019). Table 1 shows the key elements of the RTO Scheme or STAY2OWN (S20) launched by EcoWorld, which allows their customers to gain benefits from the services provided.

Table 1.0 Key Elements of S20 by EcoWorld

No.	RTO Scheme	Tenancy and Purchase Option Details
1	Low initial cost	Only three (3) months deposit (refundable).
2	Low monthly payment	Monthly payments have been structured to be similar to the market rental rate, this makes it very affordable for aspiring new homebuyers.
3	Stay first, buy later	Participants are able to live in the home immediately and experience the environment before making the big decision to purchase.
4	Savings element from rental	i. At least 30% of the rental paid may be converted into savings when the Option to Purchase is exercised. ii. The rental savings will be used to offset part of the purchase price of the home making it even more affordable to own.
5	Secure the property price and eliminate price fluctuation	i. Participants lock in the purchase price for the property today. ii. Option to Purchase exercisable after Year 1 up to the end of Year 5 gives flexibility to decide when to buy. iii. Participants can switch to a traditional mortgage once he / she is ready to purchase and qualifies for a mortgage.

Source: EcoWorld (2019)

Some of RTO schemes that have been introduced are HouzKEY by Maybank, 1Malaysia Housing Programme (PR1MA), Smart Sewa Scheme, RTO Scheme under the Melaka Housing Board (LPM), RTO Scheme by the Penang government and Jauhar Prihatin RTO Scheme in Johor (Figure 2.1).



Figure 1.0 PPR Seri Pengerang (One of Jauhar Prihatin RTO Schemes in Johor)
Source: PKPJ (2024)

These schemes assure that prospective purchasers can purchase a property without facing immediate financial hardship by emphasizing affordability, adjustable renting terms, and a gradual transfer of ownership. The shift from renting to owning is facilitated by a number of schemes, including PR1MA and state-led initiatives, which offer frozen purchase pricing and rental contributions toward ownership. Furthermore, Maybank HouzKEY and other focused schemes target higher-income workers by providing possibilities for complete financing with no down payment. Given the circumstances, RTO schemes provide a high priority on regional housing requirements, flexible homeownership routes, and financial inclusion, demonstrating a concerted commitment to offer sustainable housing alternatives in Malaysia. However, these schemes face regulatory challenges due to the lack of alignment with strata laws. The summary of these RTO schemes is shown in Table 2.0.

Table 2.0 Examples of RTO Schemes in Malaysia

Scheme Name	Eligibility	Key Features	Targeted Income Group
PPR (People's Housing Project)	● Malaysian citizens. ● Monthly household income ≤ RM3,000. ● Priority for B40 group.	● Affordable units priced RM200,000–RM300,000. ● Minimal rent with purchase option after 5–10 years.	B40 group looking for subsidized affordable housing.
Maybank HouzKEY	● Malaysian citizens. ● No current home loan. ● Satisfactory credit score.	● No down payment required. ● Locked purchase price. ● 100% financing available.	M40 and higher income earners for urban, higher-value properties.
PR1MA RTO Scheme	● Malaysian citizens aged 21+. ● Monthly income RM2,500–RM15,000. ● Priority for first-time buyers.	● Affordable homes priced RM100,000–RM500,000. ● Purchase option within 10 years with locked price.	B40 and M40 groups, especially in urban and suburban areas .

Smart Sewa Scheme (Selangor)	● Malaysian citizens. ● Monthly income RM5,000–RM15,000 (priority ≤ RM10,000). ● No other property in Selangor.	● 30% of rent credited toward purchase. ● 2–5 years rental period. ● Low deposits.	B40 and M40 for affordable, short-term RTO solutions
Melaka Housing Board RTO	● Malaysian citizens. ● Must reside in Melaka. ● Priority for B40 and M40.	● Low-cost housing priced RM180,000–RM300,000. ● Ownership transfer after 3–5 years.	B40 and M40 groups for affordable homeownership in Melaka.
Penang RTO Scheme	● Penang residents only. ● Household income ≤ RM12,000. ● Priority for B40 families.	● Low- and medium-cost homes priced RM42,000–RM300,000. ● 3–10 years rental period with purchase option.	B40 and M40 in Penang seeking affordable urban housing.
Jauhar Prihatin (Johor)	● Johor residents. ● Must not own other properties. ● Priority for B40.	● Subsidized housing for RM150,000–RM300,000. ● Purchase option after 5 years with fixed pricing.	B40 group seeking first-time homeownership in Johor.

Source: PropertyGuru (2023); Koh (2023)

III. CONCEPT OF STRATA SCHEMES

The Department of Director General of Lands and Mines defines Strata Scheme as a property development of buildings or land which are divided into parcels, accessory parcels and common property in which a management system has been set up. For example, flats, apartments, condominiums, townhouses and landed houses in gated community schemes. A strata scheme is a distinct property ownership concept that combines individual rights, group obligations, and the dynamics of communal life. This framework guarantees peaceful cohabitation and efficient administration of shared resources in high-density developments like apartments, condominiums, and gated communities.

Under the Strata Title Act 1985 (Act 318), strata plans give individual parcel owners particular legal rights that guarantee both independence and shared accountability. A strata title is given to each owner, granting them exclusive ownership, dispute protection, and authority over living arrangements, improvements, and leasing as long as they adhere to community rules. Owners can also participate in governance through Annual General Meetings (AGMs) and Extraordinary General Meetings (EGMs) because they have voting rights commensurate with their share units (Ali, 2019). Collective rights guarantee shared responsibility for common property, such as parks, corridors, and necessary services, in addition to individual ownership. All owners are required to contribute to sinking funds and maintenance fees for the upkeep of their properties, and the Joint Management Body (JMB) and later the Management Corporation (MC) make decisions about communal upkeep, renovations, and financial contributions (Izanda, Samsudin, & Zainudin, 2022; Strata Management Act 2013; Ali, 2019).

In order to preserve peace among members, strata living promotes a community-oriented lifestyle through well-structured bylaws that govern behaviour, property alterations, and shared facility usage (Wahab, 2020). By effectively resolving conflicts like unpaid fees or abuse of utilities, Strata Management Tribunals (SMT) help to avoid protracted judicial issues (Wahab, 2020). AGMs and EGMs, which examine important policies, community repairs, and financial issues, uphold democratic decision-making and guarantee openness and inclusion in the management of common areas (Ali, 2019).

IV. STRATA LAWS THAT GOVERN STRATA SCHEMES IN MALAYSIA

d. *Strata Title Act 1985 (Act 318)*

Ownership of specific parcels, such as flats, townhouses, and condominiums, is clearly defined by strata titles, whereas common property includes shared amenities like roofs, stairs, and gardens. According to Datuk Chang Kim Loong (2021), these titles are crucial for protecting owners' rights, permitting real estate transfers without developer consent, and preventing additional costs. In order to administer the property, enforce bylaws, and handle financial problems, owners having strata titles can create a Management Corporation (MC). Prior to titles being awarded, a Joint Management Body (JMB) can temporarily fill this role (Izanda et al., 2022).

e. *Strata Management Act 2013 (Act 757)*

In order to supplement the Act 318 by creating distinct legal frameworks for strata titles and strata management, the Building and Common Property (Maintenance & Management) Act 2007 (BCPMMA) was introduced. However, it was short-lived and unclear, which resulted in governance problems and poor management by inept building managers (Wong, 2019). As a more thorough law on the administration of stratified buildings, the Strata Management Act 2013 (SMA) was passed in order to remedy these problems (Mohamad, Sufian, & Kader, 2017). According to Md Zan (2016), this act offers a structured framework for the establishment of management bodies, such as the Management Corporation (MC) and the Joint Management Body (JMB), to manage common property, enforce bylaws, and handle financial obligations, including the establishment of a sinking fund account to which residents must contribute.

V. THE LIMITATIONS OF MALAYSIA STRATA LAWS IN GOVERNING RTO STRATA SCHEMES

Strata property ownership in Malaysia is governed by the Act 318 and Act 757. These laws however do not specifically provide explicit regulations for RTO strata schemes which lead to few uncertainties regarding the registration of strata title, management of strata schemes and legal rights of RTO occupiers.

Registration of Strata Title

According to the Strata Title Act 1985 (Act 318), an application for strata title can be filed as soon as the superstructure stage of construction is completed. When the building superstructure is completed, within three months of receiving the CCC, the Licensed Land Surveyor must create and submit all proposed strata plans to the Director of Survey (JUPEM) in order to apply for a Certificate of Proposed Strata Plan (CPSP). Meaning that once the building work is completed, all parcels, including ancillary parcels and common land, must be measured and depicted on the strata plan. Following the issue of CPSP, the developer must apply for strata titles within one month (Fatt, 2020).

However, there is no specific rule for strata title registration in RTO strata schemes due to the complications of dual rental and ownership phases. Section 8 STA 1985 mentions that strata title application is compulsory for original proprietor if he has the intention and agrees to sell any parcel to any person. This provision should thus apply to RTO strata schemes too as there is an intention of the original proprietor in selling the parcel, but in a unique way in which people will rent first and purchase them later. However, it is uncertain into setting the exact time of strata title application within RTO strata schemes. It is due to the difference in rental period of RTO occupiers which might last for several years. This might delay the application of strata title by the original proprietor or developer to wait for more RTO occupiers to complete the rental period to avoid fragmented title issuance. Moreover, RTO occupiers may be at risk if the strata title is delayed during the tenancy period, as it would then further delay the transfer of ownership upon the purchase completion. Such concerns emphasize the significance of transparent lease-purchase agreements and stricter enforcement of developer duties in protecting RTO occupants' ultimate ownership rights. Proper regulatory control guarantees that tenants in RTO strata schemes would not suffer any disadvantages.

Formation of Management Corporation (MC)

Under Section 46, Strata Management Act 2013, the Management Corporation (MC) is formed when the owner acquires 25% of the strata titles. This occurs after the developer has applied for and received the strata titles. Based on Section 57, Strata Management Act 2013, during the initial term, the developer oversees the property and hosts the MC's first Annual General Meeting (AGM). At this meeting, parcel owners would elect a management committee to oversee operations and make decisions on behalf of the MC. The MC committee would then be responsible for administering common property, enforcing bylaws, and maintaining financial accounts as required

by the Act 757.

Nevertheless, the formation of MC in the RTO strata scheme can be difficult due to the structure of the rental agreement, which often lasts several years before the RTO occupiers take their full ownership. Tenants under an RTO scheme are not eligible to participate in the initial formation or governance of the MC until they are officially registered as proprietors of their respective units. This creates a gap in decision-making authority throughout the rental period, as the developer or landowner maintains control, perhaps leading to dissatisfaction or a lack of tenants involvement in crucial decisions involving the management of common property. Furthermore, the renting period in RTO schemes hampers the timely establishment of the MC because RTO occupiers may not be able to take possession until their rental term expires. This delay limits RTO occupiers' capacity to vote on a management committee or handle common-area issues such as maintenance fees or repairs. During the initial period, the property is managed by the developer or Joint Management Body (JMB), which may not be in the best interests of future owners who are still under rental or tenancy agreement. As a result, the uncertainty of specific timeline for formation of MC within RTO strata schemes might delay full governance and operational stability, providing issues for successful strata property management.

Legal Rights of RTO Occupiers

The legal rights of parcel proprietors in a strata plan are substantially stronger and more secure than those of RTO occupiers, owing to ownership status. Parcel proprietors, as defined in the Strata Titles Act 1985 (STA) and the Strata Management Act 2013 (SMA), own the legal title to their unit and have enforceable rights to both their individual parcel and a proportionate share of the common property. These rights include the ability to sell, lease, or mortgage their property without seeking permission from the developer or any other party. Based on Act 318, parcel owners have the legal right to vote at Management Corporation (MC) meetings, participate in decision-making about the strata scheme, and enjoy full legal protection under strata laws.

RTO occupiers, on the other hand, are treated as tenants during the renting period and do not hold legal ownership of the property. As a result, they are unable to exercise their ownership rights, such as voting in MC meetings, mortgages, or property transfers. Rights are limited to those specified in a lease-purchase agreement, such as the use of common property during their tenancy. However, because they do not have the status of parcel proprietor, their position is fragile. For example, they rely on developers or landowners to make property decisions that may not always be in their best interests. Furthermore, RTO occupiers have no legal right to the property if the developer becomes insolvent, putting them at risk as they might lose their property. This shows the inequality in rights highlights the important issues with RTO strata schemes, especially when it comes to the rental phase. There may be conflicts and doubts because RTO occupiers are not protected by the strata legal structure, while parcel proprietors are. For instance, disagreements with parcel owners or management organisations may arise due to RTO occupiers' inability to influence decisions regarding sinking funds, maintenance costs, or by-law enforcement. Consequently, the legal rights of RTO occupiers during the rental period remain uncertain, potentially leading to disputes, mismanagement, or inequitable treatment within the strata scheme, thereby undermining both the effectiveness of the management framework and the interests of all stakeholders involved.

VI. COMPARATIVE LEGAL FRAMEWORK: NEW SOUTH WALES, AUSTRALIA

The following table compares important legal concerns between Malaysia and New South Wales (NSW), Australia, to better understand how Rent-to-Own (RTO) strata schemes function in various legal systems. The comparison, which focuses on important legal, structural, and operational elements of both systems, is based on the material covered in the entire study.

Table 5.0 Comparison between RTO strata schemes in NSW, Australia and Malaysia

Element of Analysis	New South Wales, Australia	Malaysia
Strata Title Registration	Strata titles need to be registered which allow RTO occupiers to register caveat and gain recognition.	Strata title for RTO schemes are not clearly mentioned when they should be registered, which delays legal recognition.
Formation of Management Body	Owners Corporation (OC) is automatically formed after the strata plan is registered.	Formation of MC needs to wait until 25% of owners acquires their strata title which could

		take up to several years.
Legal Rights of RTO Occupiers	RTO occupiers may attend general meetings of Owners Corporation, their participation in strata governance is being recognized.	No clear provisions mentioned the rights of RTO occupiers to attend any general meeting, and they have no statutory rights to engage in strata governance.

Source: NSW Government (2024); The Strata Collective (2019)

New South Wales is one of the states in Australia that has implemented their legal framework in governing RTO strata schemes. RTO strata schemes in NSW Australia are governed by NSW Strata Schemes Management Act (SSMA) 2015 and Residential Tenancies Act (RTA) 2010. Based on Table 5.1 above, it is clear that RTO systems in NSW, Australia and Malaysia are operating differently, especially when it comes to legal protection and clarity.

In the context of strata title registration, strata titles must be recorded as soon as possible in NSW. RTO occupiers benefit from this since it allows them to safeguard their interest in the property, for instance, by submitting a caveat. In Malaysia, when these titles should be registered is not specified, and its delay may keep RTO occupiers from obtaining any kind of legal recognition for years and perhaps compromising the claims of the occupiers.

When it comes to the formation of a management body, an Owners Corporation (OC) can be automatically established according to NSW's procedure once the strata plan is registered which guarantees organized management and early governance. In Malaysia, however, the Management Corporation (MC) can only be formed once 25% of unit owners have secured strata titles, which can be severely delayed in RTO developments, leaving a management void in the interim.

Lastly, in New South Wales, the SSMA 2015 permits tenants, including those under rent-to-own schemes to attend general meetings of the Owners Corporation if they are nominated by the property owner. Even though they are not able to vote, their presence enables them to participate and be aware of how the strata plan is run. Whereas in Malaysia, due to a lack of clarity regarding the role of RTO tenants within strata schemes, these occupiers often do not attend meetings, or developers—being the sole members of the Management Corporation (MC) during the initial period—may not convene any meetings to discuss strata management matters. This situation can lead to potential disputes, mismanagement, or inequitable treatment within the strata scheme, thereby undermining both the effectiveness of the management framework and the interests of all stakeholders involved.

As a result, although RTO is used to assist house ownership in both countries, NSW has a clearer legal framework that gives some degree of security to the tenants. In contrast, Malaysia still has a lot of work to do to make sure that RTO occupiers are protected under the law.

VII. CONCLUSION

Malaysia’s current strata laws do not sufficiently address the complexities of RTO schemes, leading to governance gaps, disputes, and uncertainty regarding legal rights of the RTO occupiers. Tenants are at risk due to the lack of legal recognition for RTO occupiers during the renting period and the delays in the registration of strata titles. On the other hand, the strata law in the NSW demonstrates how structured the legal frameworks safeguard RTO occupants and facilitate their seamless inclusion into strata governance. Recognising RTO occupiers as stakeholders, requiring prompt strata title registration, and permitting progressive inclusion in Management Corporations are all examples of legislative reforms that should be implemented to enhance RTO strata schemes management. Although the Ministry of Housing and Local Government (KPKT) has been promoting RTO initiatives to help buyers with limited funds and alleviate Malaysia's property overhang, existing strata laws may provide reputational issues. Borhan Aman Shah, chairperson of the Selangor Housing and Culture Committee, has called on the government to examine current strata regulations to make sure they are still applicable and efficient (The Star, 2024). Malaysia's current regulations might be significantly improved by adopting legislative frameworks from nations with effective RTO strata schemes governance.

ACKNOWLEDGMENT

The main author would like to express his gratitude to Faculty of Built Environment and Surveying of Universiti Teknologi Malaysia, Skudai, especially the supervisor for funding this publication.

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DETERMINING THE SATISFACTION LEVEL OF SHOPPING CENTRE MANAGEMENT TOWARDS FACILITIES MANAGEMENT SERVICE DELIVERY IN REGIONAL SHOPPING MALLS IN KUALA LUMPUR

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ABSTRACT

Shopping malls play a crucial role in urban economies, particularly in Kuala Lumpur, where they contribute significantly to the retail sector and overall GDP. Effective facilities management (FM) is essential to ensure the seamless operation of shopping malls, encompassing maintenance, security, cleanliness, and tenant satisfaction. While previous studies have explored consumer satisfaction with shopping mall FM services, limited research focuses on the satisfaction levels of shopping mall management toward FM service delivery. This study aims to address this gap by assessing the satisfaction of shopping mall management in regional shopping malls in Kuala Lumpur. A quantitative research approach is employed, involving a structured questionnaire survey distributed to shopping mall management teams. The study seeks to identify the types of FM services provided, determine the critical FM services required for optimal mall operations, and evaluate shopping mall management's satisfaction levels. Statistical analysis using SPSS will be conducted to analyse the collected data, providing insights into key FM performance areas and areas requiring improvement. The findings of this research are expected to highlight the FM services that significantly impact shopping mall operations and identify challenges faced by management in ensuring high-quality service delivery. By understanding management satisfaction levels, the study can contribute to the enhancement of FM strategies, offering practical recommendations for improving FM service efficiency. The results will be valuable in optimizing mall operations and sustaining competitiveness in the retail sector.

Keywords**:** Facilities management, shopping mall management, service delivery, satisfaction level

I. INTRODUCTION

Shopping malls are central to urban life and the retail industry, serving as hubs for shopping, entertainment, and community activities. Shopping malls play a big role in supporting the retail sector, helping businesses grow, and providing employment opportunities. Facilities management (FM) services play an important role in supporting the daily operations of shopping malls. Facilities Management (FM) is essential in the daily running of services and the overall growth of a business due to its role in making the working environment conducive for both staff and clients (Masjoni, 2015). To manage their shopping mall, the management needs to adopt their own FM strategy. Organizations adopt various strategies to FM to realize their desired aims, but the distinctiveness of a strategy depends on how it is sourced (Atkin and Brooks, 2015; Ikediashi et al., 2015). FM can either be done using an in-house strategy where FM services are directly undertaken by a team of dedicated staff and resources that have been employed by the firm itself (Atkin and Brooks, 2015; Ikediashi, 2014; Fick, 2012; Barrel and Baldry, 2003; Luciani, 2005) or by outsourcing where a third-party service provider undertakes the FM role (Amos and Gadzekpo, 2016; Atkin and Brooks, 2015; Toe, 2015; Ahamed et al., 2013; Olusegun et al., 2013). It can also be done by a mix-strategy where some services are provided in-house while the others are outsourced (Atkin and Brooks, 2015).

Outsourcing is a common practice aimed at leveraging the expertise and efficiency of professional service providers, enabling mall management to focus on strategic goals and tenant relations. Outsourcing is increasingly

becoming popular among shopping malls (Toe, 2015; Doamekpor, 2016; Amos and Gadzekpo, 2016; De Mendonca and Zhou, 2019). To define outsourcing, Olusegun et al., (2013) that it entails the process of contracting certain specialized services out to third-party experts so that the firm can focus on its core competencies. To remain focused on their core businesses for competitive advantage, most organizations/building owners outsource some or all FM services (Lok et al., 2021a, 2021b, 2021c; Tannor et al., 2022b). In a similar study on institutions of higher learning, Amos and Gadzekpo, (2016) found that the reason why public polytechnics in Ghana outsource certain FM services is because undertaking such services in-house could divert management time from academic work which is the core competency to non-core services. In Ikediashi (2014) and Ikediashi et al (2015), this benefit of outsourcing was termed as 'strategic' because it made it possible for public hospitals in Nigeria to dedicate time, energy, and resources to their core activity of quality healthcare delivery while non-core services such as cleaning, landscaping, catering etc are taken care of by third-party FM service providers. The common idea that runs through all the definitions of outsourcing is the contracting of activities to a third party outside of the organization (Tannor et.al, 2021; Ikediashi et al., 2015; Ikediashi,2014). The result of any outsourcing activity should be quality services that support the goals of the firm. (Kurdi et al., 2011; Amos & Gadzekpo,2016).

Consequently, by outsourcing FM tasks to specialized subcontractors, shopping mall management may expect high-quality and consistent service delivery that aligns with the mall's operational goals. This reliance on subcontractors introduces challenges that can directly impact the satisfaction levels of the shopping mall management. Problems such as delays in addressing operational needs, inconsistent service standards, and poor communication may be common and will disrupt the operation of the mall. Therefore, the satisfaction level of shopping mall management with FM service delivery is a critical metric for evaluating the success of these services. Masih (2007) identified the challenges of mall management to include issues such as positioning a mall, zoning and tenant mix, promotions and marketing, and facility management in terms of infrastructure, traffic and ambiance management, and finance management as issues surrounding shopping mall management. In some literature, the strategic advantages that come with engaging an agent to provide FM services were said to have the potential to increase productivity and operational capabilities of the principal as well as satisfaction for its users because of the quality of FM services that are undertaken by the expert agent (Tannor et al., 2022b; Agburu et al., 2017; Amos and Gadzekpo, 2016a, 2016b). The main aim of this research is to investigate the satisfaction level of the shopping centre management towards facilities management service delivery in a regional shopping mall in Kuala Lumpur. To achieve the aim, the following objectives have been identified as follows:

1. To identify the types of facilities management services delivered in regional shopping malls.
2. To determine the critical facilities management services in regional shopping malls.
3. To determine the satisfaction of the shopping mall management towards the delivery of facilities management services.

This highlights that shopping mall management may have varying satisfaction levels with the facilities management services delivered in their shopping malls. In a nutshell, understanding how satisfied shopping mall management is with FM service delivery is important for improving how malls operate and ensuring their long-term success. This study solely concentrates on the regional shopping malls in Kuala Lumpur because Kuala Lumpur's shopping mall is one of the biggest contributors to Malaysia's GDP in the retail industry.

II. LITERATURE REVIEW

The Shopping mall, as a very successful land use, has long dominated the retail landscape of most advanced nations by serving as neighbourhood, community, regional and super-regional centres (Wang, Zhanga and Wang, 2006; Ho, 2005). According to Matthysen (2016:3), a shopping centre is a group of retail and other commercial establishments that are planned, developed, owned and managed as a single property. According to Cant (2010:3), "A retailer may be seen as a business that focuses its marketing efforts on the final consumers, to sell goods or services to them". The role of shopping centres can be seen from different perspectives. It can be seen as a place of business, it can be viewed as a property, and lastly as an investment (Matthysen 2016:3). Regional shopping centres have shown internal growth since the last part of the 1990s and have become a prominent feature and integral part of the modern urban landscape (Prinsloo 2010:1). With the growth of the malls' industry, where various new malls were built, and millions of square feet of retail space were added to existing shopping malls each year (Berman and Evans, 2004). The retail industry of any given country contributes largely to the economy (Prinsloo 2010:1) and provides many different job opportunities to the citizens (Cant 2010:4). Shopping centres have shown the strongest growth in real estate in recent years and have become a prominent feature and integral part of the modern urban landscape (Vitorino 2012:175).

In emerging countries such as Mauritius however, the mall industry seems to be evolving at an accelerating pace (Juwaheer, Pudaruth and Ramdin, 2013). Currently, one of the biggest contributors to Malaysia's GDP is the retail industry, which is mostly supported by Kuala Lumpur's shopping malls.

According to Savills Malaysia Research (2024), new retail supply increased by 2.5 million sq ft from three new completions: The Exchange TRX (with a net lettable area of 1.35 million sq ft), Pavilion Damansara Heights Phase 1 (533,000 sq. ft), and KSL Esplanade Mall (650,000 sq. ft), two of which are in the KL suburbs and one in Outer KL in 2023. Shopping malls are integral to urban areas, especially in a metropolitan city like Kuala Lumpur. As Malaysia's capital city and economic hub, Kuala Lumpur has many well-known shopping malls and to ensure smooth operations, these malls rely heavily on facilities management (FM) services. Facility management (FM) has become one of the fastest-growing sectors in the recent decade. According to Dell (2008), facilities management is critical to an organization's survival and performance in today's fast-paced world. Facility management (FM) plays an important role in ensuring that users of facilities enjoy conducive environments that allow them to offer quality services to their clients while achieving the best returns from their activities (Masjoni, 2015). BIFM (2006) also highlighted the importance of effective facilities management for the delivery of strategic and operational objectives, as well as for day-to-day operations and the creation of a safe and efficient working environment. Facility management (FM) ensures that buildings are conducive for users and can serve their purpose over their life span (Støre-Valen, 2021; Tannor et al., 2022b). It clearly shows the importance of facilities management in supporting the efficient operation of buildings and spaces, including shopping malls.
Facility management, by definition, is a multi-skilled process that promotes an organization's core business by integrating the physical workplace and its people (Barrett P,2004). Facility management, according to Kincaid (1994), is a supportive service provided by an organization to meet the demands of its core business. One's definition of FM may vary according to context, nature of the environment, culture, organizational setting, goals, and the individual's interest (Noor et al., 2014; Price 2006; Anna-Lisa, 2005). Barret and Baldry (2003) described facilities management (FM) as an approach that integrates various disciplines to maintain, improve, and adapt an organization's buildings and infrastructure. The International Facilities Management Association (2006) defines FM as a profession that ensures the functionality of the built environment by integrating people, place, processes, and technology. The British Institute for Facilities Management (2008) states that FM is the integration of multi-disciplinary activities within the built environment, managing their impact on people and the workplace. In the context of buildings, Atkin and Brooks (2015) defined FM as ''an integrated approach to operating; maintaining, improving and adapting the building and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of the organization''.

In the Twelve Malaysian Plan, Malaysia has experienced increasing demand for services in maintenance, repair and overhaul as 42.2% was contributed to the 2020 total revenue. Facilities management is still considered an emerging field of study (Goyal and Pitt, 2007). Facilities management is now regarded as a significant commercial area in various African countries, including Nigeria, South Africa, Ghana, Asian Nations, including Japan, Malaysia, Singapore, etc and many parts of the world, and facilities management approaches are being used employed. Facilities Management (FM) has increasingly become a major topic of discuss in even in 21st century. According to Ikediashi, Ogunlana and Boateng (2014), FM is said to be acquiring increasing popularity all over the globe, with several sourcing strategies springing up for FM services provision. The field has evolved over time from what was once thought to be limited to facility maintenance to a profession that includes building and infrastructure management for organisations in order to create an environment that supports their main goals (Ikediashi et al. 2012). Over the years, innovation has caused FM in buildings to evolve from merely managing buildings to an integral part of the primary and support services of organisations (Price et al., 2011; Noor and Pitt, 2009). Facilities management encompasses a wide range of services. FM services normally include building repairs and maintenance of the building, utility management, ground services, occupational, environmental safety and health, car park and public safety, architectural, engineering and construction services, information technology and communications. Thus, according to published research on sustainable FM can be assigned to eight categories: building performance; sustainability tools and standards; user perception, satisfaction and productivity; sustainability management; construction and sustainable building materials; building design and sustainability; urban development; and benefit of green buildings (Nielsen et al., 2016). According to Cable, J.H. and Davis, J.S. (2004) an adequate facility management can result in a support aligned with the organization's mission, the anticipation of future facility requirements, the ability to foresee results of current management decisions, and the reducing of the operational inefficiencies. These services are critical for creating a safe, clean, and appealing environment for tenants and shoppers while supporting the mall's overall functionality. Thus, it shows the importance of determining the types of FM delivered and which are the critical FM as every property is different and not all functions may be applied on.

Mall management can therefore be said to be a critical factor for the success of malls and the retail industry across the world (Wang et al, 2006; Ho, 2005). Mall management, which involves all the activities that are carried out by mall managers to ensure the delivery of a befitting space in a mall and guarantee efficient functioning of all ancillary facilities for excellent mall experience, has the potential for engendering patronage. To achieve these objectives, management relies heavily on effective FM services to maintain the mall's infrastructure and deliver

consistent quality. Facilities management serves as the foundation for all operations (M. Noor and M. Pitt, 2010). The ability of a shopping mall to provide a seamless and enjoyable experience for visitors is closely tied to the efficiency of its FM services. From a functional dimension, Barrel and Baldry (2003) indicated that service quality is determined by its delivery method. It looks at how the service provider delivers the service. Consequently, shopping mall management faces challenges in making a mall successful as ensuring the mall's success requires consistent effort to balance these responsibilities while dealing with the complexities of facilities management services. Current shopping mall management encounters many different challenges, which include identifying, understanding, and meeting the ongoing needs of consumers, retailers, and mall management (Matthysen 2016:3). In 2014, Chaturvedi, Chakraborti, Bartaria, and Neve identified the challenges of shopping mall management to include: identifying, understanding and meeting the ongoing needs of consumers, retailers and mall owners, establishing excellent management teams and the quality of management services in a shopping mall; the quality of management; and setting up a competent team. While there is considerable research on consumer satisfaction with the FM services delivered in shopping malls, studies focusing on the satisfaction level of shopping centre management with the FM services delivered are limited. In a nutshell, understanding the satisfaction level of shopping mall management is crucial as they are responsible for coordinating FM services and ensuring the service delivery aligns with the mall's operation and strategic objectives.

In summary, the effectiveness of FM service delivery, whether in-house, outsourced, or mixed has direct implications for service quality and, ultimately, the satisfaction level of shopping centre management as shown in Figure 1 below. Understanding how these factors interact is essential not only for improving mall performance in Kuala Lumpur but also for advancing best practices in the wider facilities management industry. By identifying the most critical FM services and evaluating satisfaction levels, this study supports the findings can guide mall operators and FM providers in enhancing operational efficiency and service quality.

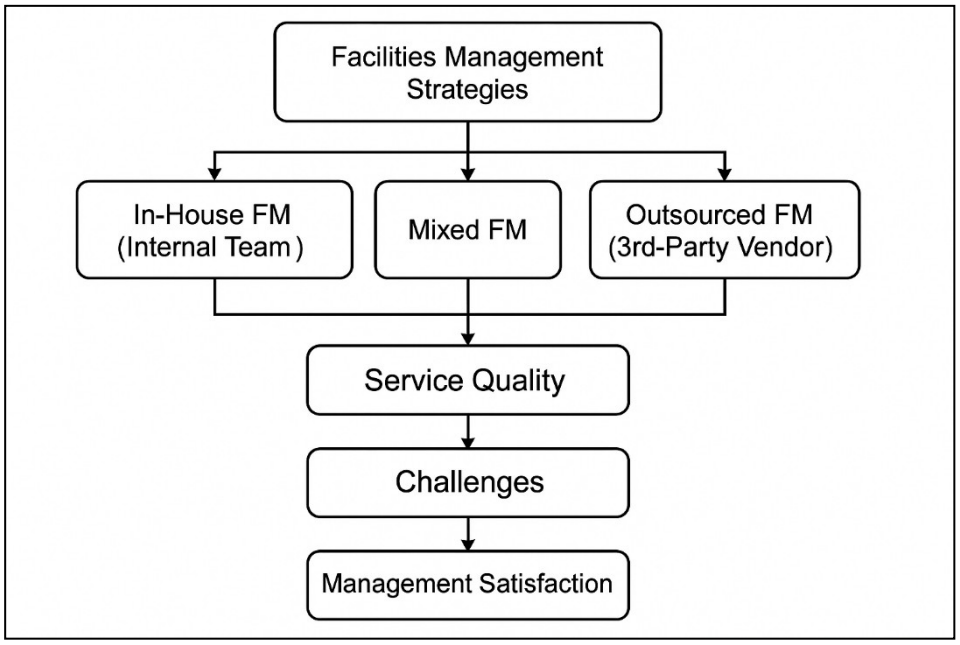


Figure 1.0: Conceptual Framework Diagram

III. RESEARCH DESIGN AND METHODOLOGY

This research adopts a quantitative method as it is suitable for analysing the satisfaction level of shopping centre management towards facilities management service delivery in regional shopping malls in Kuala Lumpur. This approach is appropriate because the data is structured numerically or can be readily converted into numerical form. Quantitative research is characterized by objectivity, deductiveness, generalizability, and the use of numbers, making it ideal for this study. The research adopted the following design which includes three phases:

A. Phase 1: Literature Reviews

The literature reviews are carried out by gathering resources from newspapers, reports, bulletins, technical reports, journals, books, guidelines, and regulations. All information gathered will provide an understanding of the importance of studying satisfaction levels of shopping mall management in regional malls in Kuala Lumpur. Besides, the literature review will review the types of facilities management services provided in shopping malls, the critical facilities management services in regional shopping malls, and the expectation of shopping mall management towards facilities management service delivery in regional shopping malls.

B. Phase 2: Questionnaire Survey

To meet the research objectives, a structured questionnaire will be developed to collect primary data from shopping centre management in regional malls in Kuala Lumpur to identify the types of facilities management provided in their mall and the critical facilities management services in a regional mall. This survey aims to determine the satisfaction level towards facilities management service delivery. The questionnaire will be distributed via email or in-person to the shopping mall management. Statistical analysis will be used to examine the data collected. This survey aims to generalize findings from a sample to the entire population to conclude it.

C. Phase 3: Data Analysis

After collecting data, statistical analysis will be performed using SSPS Windows (Statistical Package for Social Science. These include descriptive statistics and inference statistics. The purpose of data analysis is to determine the types of facilities management services provided in shopping malls, the critical facilities management services in regional shopping malls, quantify satisfaction levels of shopping mall management, and identify any services with low satisfaction in regional shopping malls.

CONCLUSION

This study provides critical insights into the satisfaction levels of shopping mall management regarding facilities management (FM) service delivery in regional shopping malls in Kuala Lumpur. By examining key FM services and identifying areas for improvement, the findings can guide mall operators and FM providers in enhancing operational efficiency and service quality. The research also contributes to the broader discourse on FM effectiveness, offering data-driven recommendations that support sustainable mall operations. Future studies may expand on this work by exploring comparative analyses across different retail environments or integrating qualitative perspectives to gain deeper managerial insights. Strengthening FM strategies based on management satisfaction will be essential in ensuring long-term competitiveness and resilience in the evolving retail landscape.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Department of Real Estate, Universiti Malaya for their invaluable institutional support and resources. Special thanks are extended to dedicated supervisors for their expert guidance, constructive feedback, and efforts in securing the necessary funding for this publication. This research was financially supported by the 17th RISM International Surveying Conference for Undergraduates (ISCU 2025), which provided access to essential tools and publication opportunities. We are also deeply grateful to the participants and industry partners whose insights enriched the practical significance of this study. On a personal note, we extend our heartfelt appreciation to our families and friends for their unwavering support, patience, and encouragement throughout this challenging yet rewarding journey. Lastly, we sincerely thank the reviewers and editors of the International Journal of Engineering and Innovative Technology (IJEIT) for their thorough evaluation and insightful suggestions, which significantly enhanced the clarity and impact of this manuscript. Their contributions reflect the collaborative spirit that drives meaningful academic progress.

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DEVELOPING A BUILDING MAINTENANCE STRATEGY FOR LOW-RISE, LOW-COST HOUSING IN MALAYSIA'S NORTHERN REGION: A CONCEPTUAL FRAMEWORK FOR ADDRESSING TROPICAL CLIMATE CHALLENGES

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ABSTRACT

Building maintenance is essential to preserve safety, functionality, and durability, especially in low-rise, low-cost housing. In Malaysia's northern region, tropical climate conditions (e.g., high humidity, intense rainfall, and extreme heat) accelerate the deterioration of building components, posing challenges to long-term upkeep and occupant well-being. A mixed-methods approach incorporated interviews with maintenance personnel, document analysis, site observations, and resident surveys. The study identified climate-induced deterioration patterns, evaluated current maintenance practices, and assessed the role of community participation. Data analysis focused on common building defects, maintenance responsiveness, and gaps in resource allocation. Frequently reported defects included roof leaks, wall cracks, paint peeling, mold growth, and blocked drainage systems. Delayed interventions, limited budgets, and reactive maintenance practices often aggravated these issues. Roofs, external walls, and plumbing systems were particularly vulnerable to moisture and thermal stress. The study highlights the absence of systematic preventive maintenance and inadequate stakeholder coordination. A climate-responsive, condition-based preventive maintenance framework is proposed. It emphasizes periodic inspections, early defect detection, the use of durable materials, and structured community involvement to improve maintenance effectiveness. This study provides a practical strategy to transition from reactive to proactive maintenance in tropical environments. By integrating climate-specific risks and social dynamics into planning, the framework enhances decision-making for local authorities and facility managers. It supports improved building performance, extended asset life, and better living conditions in resource-constrained housing developments. The tropical climate significantly impacts the integrity of low-rise, low-cost housing. A structured, preventive maintenance strategy tailored to environmental conditions is critical to reduce deterioration, control costs, and ensure long-term sustainability in Malaysia's northern region.

Keywords: building maintenance, low-rise buildings, tropical climate, structural durability, building performance

I. INTRODUCTION

Urban landscapes in rapidly developing regions such as Penang, Malaysia, are increasingly characterized by low-rise, low-cost housing, which serves as a critical solution to the growing demand for affordable housing. These buildings not only provide shelter for an expanding urban population but also symbolize the country's economic growth and modernization efforts. However, Ramli *et al.,* 2015 stated that the maintenance and durability of these structures face significant challenges due to the tropical climate, which accelerates the degradation of building materials and systems. Malaysia's climate, characterized by consistently high temperatures, high humidity, and heavy rainfall, significantly impacts the longevity of construction materials and building components, posing a unique challenge for maintaining low-rise, low-cost housing in the northern region.

As climate change continues to be a global concern, its localized effects, particularly on the built environment, have become more pronounced. Malaysia, situated in Southeast Asia and encompassing both Peninsular Malaysia and Malaysian Borneo, experiences a tropical climate marked by high moisture levels, intense rainfall, and frequent storms, primarily due to its coastal position and exposure to monsoonal weather patterns (Munawar *et*

al., 2024). The continuous exposure of buildings to these environmental conditions accelerates the deterioration of materials and structures. Corrosion, mold growth, rotting of timber, and the weakening of concrete and masonry are common issues faced by low-rise buildings in this climate, leading to increased maintenance costs and reduced safety and comfort for residents. The problem is compounded by the growing urban population and limited resources available for maintaining these buildings, particularly in low-cost housing sectors where funding is constrained.

This study aims to develop a climate-responsive maintenance strategy for low-rise, low-cost housing in Malaysia's northern region. It considers the tropical climate's impact on material durability and proposes a proactive framework addressing humidity, rainfall, and coastal winds. The strategy emphasizes durable materials, regular inspections, innovative technologies, and sustainable practices to enhance resilience and longevity. It also promotes cost-effective solutions, community engagement, and capacity building. By bridging gaps in existing maintenance methods, the framework ensures safe, functional, and sustainable buildings, supporting urban modernization, economic growth, and environmental sustainability in the region.

A. Building Maintenance in Malaysia

Malaysian building maintenance faces aging infrastructure, limited resources, and insufficient staff training. According to Zhi Ling *et al.,* 2024, to enhance maintenance efforts and ensure compliance with safety and legal standards, it is essential to adopt technology, engage stakeholders, and allocate funding for training initiatives.

Building maintenance is crucial in Malaysia to prevent minor issues from escalating, as neglected maintenance can lead to higher repair costs and a reduced building lifespan. However, delays often arise due to factors such as rising costs, poor scheduling, and inadequate planning, highlighting the need for effective mitigation strategies (Norazam et al., 2023).

B. Low-Rise Low-Cost Building Maintenance

The use of substandard materials in low-rise structures often leads to significant deterioration. Additionally, Lekan *et al.,* 2021 figure that, poor maintenance practices among residents, stemming from limited professional participation in training programs, contribute to the stagnation of building maintenance efforts.

Low-cost strata schemes often struggle with limited resources and a lack of resident support, posing challenges to maintenance across various building types. In low-rise buildings, factors such as aging, inadequate repair methods, and neglect result in poor upkeep. According to Kumalasari *et al.,* 2003, environmental conditions further accelerate deterioration, emphasizing the need for improved maintenance practices to prevent failures.

C. Climate Change Definition and Effects on the Building

"Climate change" refers to significant shifts in temperature and weather patterns over time. According to Liang *et al.,* 2022, its effects on buildings include increased vulnerability to extreme weather events, leading to structural damage, reduced reliability of critical infrastructure, and the need for resilient, sustainable urban strategies.

Human activities like burning fossil fuels, deforestation, and industrial processes, which emit significant volumes of greenhouse gases like carbon dioxide and methane into the atmosphere, are the main causes of these changes. By trapping heat, these gases cause global warming and the ensuing disturbances of ecosystems and weather patterns.

a. Heavy downpours can overwhelm drainage systems, leading to waterlogging, leaks, and flooding that damage building foundations and interiors;
b. High humidity fosters the growth of mold and fungi, which can damage building materials and negatively impact indoor air quality;
c. Moisture accelerates rusting in metal components such as reinforcements, beams, and fasteners, weakening the structure over time;
d. Frequent cycles of heating and cooling can cause materials to expand and contract, leading to cracks, leaks, and structural weaknesses; and
e. Climate change accelerates wear and tear on buildings, requiring more frequent inspections, repairs, and upgrades to ensure safety and functionality.

II. METHODOLOGY

A. Qualitative Method

Understanding qualitative approaches is essential to comprehending research. They present a comprehensive and nuanced picture of the phenomenon being studied, offering deep insights that are frequently not possible with just quantitative approaches. Numerous disciplines, including the humanities, social sciences, and even the natural sciences, employ qualitative approaches as determined by Doris *et al.,* 2024.

For this study, the qualitative approach is crucial because it offers deep insights into the difficulties and solutions associated with preserving low-rise low-cost structures in the northern region's tropical environment. The qualitative method enables the researcher to collect in-depth viewpoints from building managers, maintenance staff, residents, and industry experts through focus groups, interviews, and document analysis.

B. Quantitative Method

Quantitative analysis is a research method that involves collecting, analyzing, and interpreting numerical data through statistical techniques. According to Devi *et al.,* 2024, accurate data for statistical analysis can be obtained from surveys, experiments, and secondary sources.

The quantitative approach is essential to this study because it offers measurable and objective data to assess how Malaysia's tropical environment affects the northern region's low-rise low-cost building upkeep. Numerical data on variables such as the frequency of maintenance tasks, expenses incurred, material deterioration rates, and climate metrics (e.g., humidity and rainfall levels) can be gathered using quantitative approaches.

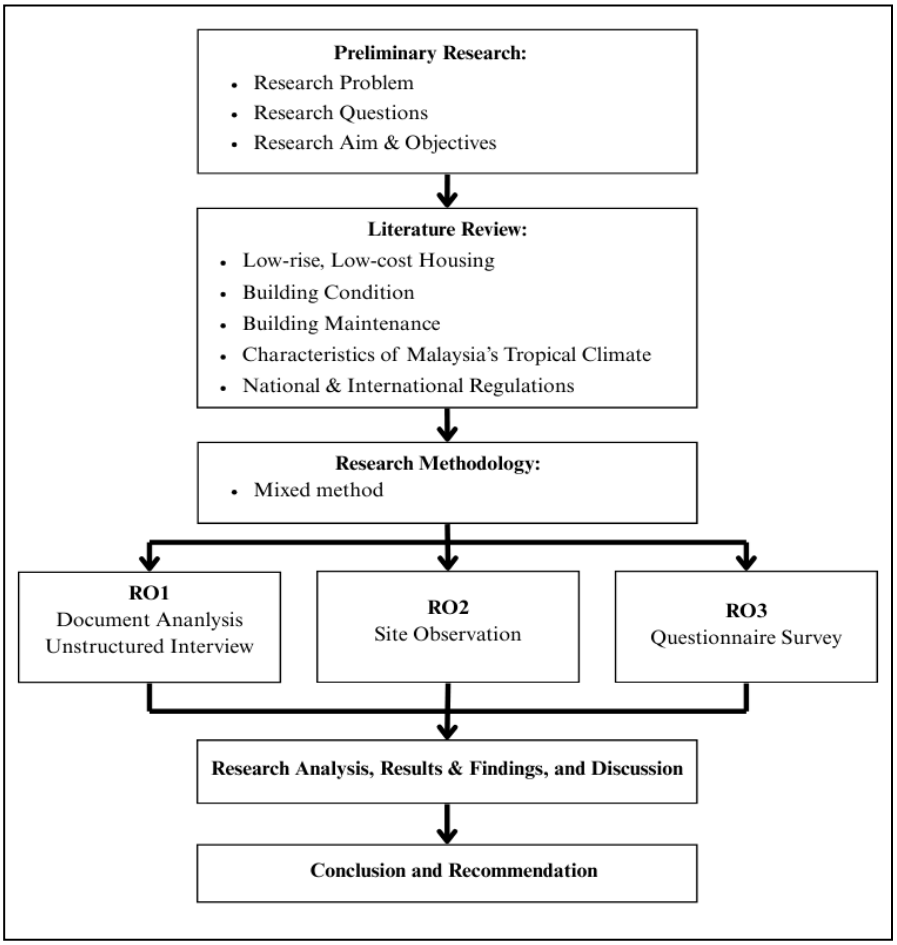


Figure 1.0 The Figure of Research Framework in Research Methodology

III. CONCEPTUAL FRAMEWORK

Malaysia's northern region experiences a tropical climate characterized by high humidity, heavy rainfall, extreme heat, and coastal winds. These environmental factors accelerate the deterioration of building materials, leading to increased maintenance needs, structural vulnerabilities, and higher long-term costs. Low-rise, low-cost housing, in particular, faces challenges due to limited resources, inadequate maintenance practices, and poor material durability.

A conceptual framework for addressing tropical climate challenges is a structured model that identifies key factors, relationships, and strategies to minimize the impact of a tropical climate on buildings, infrastructure, and the environment. In the context of building maintenance, it serves as a guide for designing effective, climate-responsive solutions. This framework offers a systematic approach to developing maintenance strategies that improve the resilience, sustainability, and durability of buildings in tropical regions.

This conceptual framework provides a systematic and adaptive approach to overcoming tropical climate challenges in low-rise, low-cost housing maintenance. By integrating durable materials, proactive strategies, sustainable technologies, and community participation, the framework aims to enhance the longevity, resilience, and affordability of housing in Malaysia's northern region. This approach aligns with broader urban modernization, economic growth, and sustainability objectives, ensuring safe and livable housing for future generations.

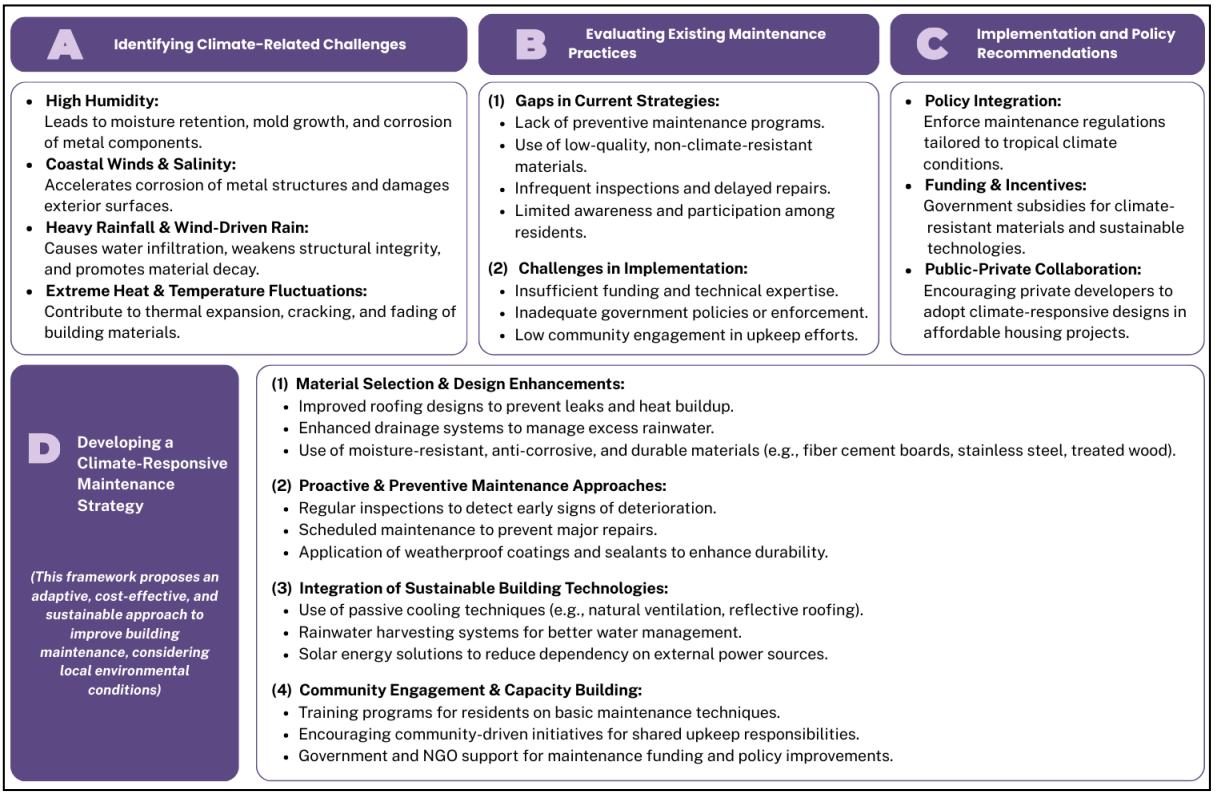


Figure 2.0 The Figure of Key Components of The Conceptual Framework

CONCLUSIONS

The maintenance and longevity of low-rise, low-cost housing in Malaysia's northern region are challenged by the tropical climate, including high humidity, heavy rainfall, extreme heat, and coastal winds, which accelerate material deterioration and increase maintenance needs. This study identifies key climate-related factors affecting building durability, such as moisture accumulation and wind-driven rain, and highlights gaps in current maintenance practices. To address these challenges, a conceptual framework is proposed, emphasizing adaptive, cost-effective strategies, including material selection, proactive maintenance, and sustainable technologies. Community involvement and capacity building are also prioritized to ensure long-term success. By implementing these tailored strategies, the resilience, safety, and sustainability of low-cost housing can be significantly improved, supporting urban modernization, economic growth, and a more livable built environment.

ACKNOWLEDGEMENT

We thank the School of Housing, Building, and Planning, Universiti Sains Malaysia, for the conducive environment to conduct this study. In addition, the authors thank the anonymous reviewers for their constructive comments to improve the quality of this work. Finally, the authors thank the participants, for their cooperation and valuable responses that formed the basis of this study.

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EXPLORING CAUSAL FACTORS AND MITIGATING ACTIONS IN CONTROLLING CONTRACTORS' BUDGETS IN BUILDING REFURBISHMENT PROJECTS

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ABSTRACT

Building refurbishment projects (BRPs) are critical for reinvigorating aging infrastructure, offering economic and environmental benefits by upgrading existing structures for better functionality and standards. Despite BRPs offering these advantages, we cannot avoid budgetary control issues concerning unforeseen items such as hidden structural deficiencies, outdated systems as well as regulation changes causing cost overrun. This conceptual paper focuses on exploring the factors that can contribute to difficulties in controlling budget for the contractors in BRPs and how to mitigate these factors. Through literature review, it was discovered that the primary causal factors include unforeseen structural issues (e.g., hidden damages, outdated systems), regulatory changes, scope creep, market volatility (fluctuating material and labor costs), and stakeholder mismanagement. To address these challenges, contractors could employ mitigating actions such as effective planning and risk assessment, stakeholder engagement, advanced project management tools, value engineering, and flexible procurement strategies. To affirm the relevancy of these factors and mitigating actions for refurbishment projects contractors in Malaysia, this paper proposes to conduct further research via qualitative approach in which an interview process will be planned with main contractors experienced in executing refurbishment projects. The interview method was chosen for its ability to provide in-depth insights into contractors' experiences, challenges, and strategies, which are difficult to capture through quantitative methods. This paper contributes to the literature by synthesizing the causal factors and mitigating actions for budget control in BRPs, offering a foundation for future empirical research and practical recommendations for contractors to improve budget management and project outcomes.

Keywords: Building Refurbishment Project (BRPs); Causal Factor; Budget Control; Mitigating Action; Contractor

I. INTRODUCTION

Building refurbishment projects (BRPs) play a crucial role in revitalizing aging structures, extending their life cycle, and contributing to sustainable urban development. BRPs offer environmental benefits, including resource conservation and reduced construction waste, while addressing the challenges posed by deteriorating buildings (Ali et al., 2018; Yacob et al., 2019). However, managing the financial aspects of these projects is particularly challenging. The unpredictable nature of upgrading existing structures introduces complexities that often lead to unforeseen costs and budget overruns (Yacob et al., 2019; RICS, 2022).

Refurbishment projects differ significantly from new construction in that they involve retrofitting, repairing, or upgrading existing structures, often uncovering hidden issues such as structural deterioration, outdated systems, or regulatory compliance concerns (Nor et al., 2024; Siti, 2015). These unforeseen complications make accurate cost estimation and budget control particularly difficult, as contractors must adapt to changing conditions and address problems as they arise (Mohd et al., 2023). For instance, unexpected issues such as deteriorating structural elements can lead to substantial increases in project costs (Ali et al., 2020). As a result, BRPs often experience budget overruns.

The growing concern over budget control in BRPs is particularly relevant in Malaysia, where the demand for refurbishment projects has risen due to the aging building stock (Ali et al., 2015; Masrom et al., 2021). According to the Royal Institution of Chartered Surveyors (RICS) (2022), cost overruns in refurbishment projects can reach as much as 30%, underscoring the need for effective financial management strategies.

II. LITERATURE REVIEW

B. *Building Refurbishment Projects (BRPs)*

Refurbishment activities in BRPs modify, restore, renovate and upgrade existing buildings to enhance functionality while satisfying usage needs and improving aesthetics and value as well as extending the building's lifespan (Azlan et al., 2005). BRPs differ from new construction because they transform existing structures to repair damages while modernizing buildings in accordance with modern comfort standards (Iñiguez, 2025). The main objective of building retrofit programs seeks to optimize financial returns while improving sustainability by both decreasing energy usage and environmental footprint (Tsikos & Poli, 2024).

Key Aspects of BRPs

Building and repair projects in Malaysia differ in their scope and function thus segmentation can occur through size dimensions and construction approaches alongside building types and intended objectives and procurement choices. According to CIDB (2022) the organization divides BRPs into four distinct groups which include upgrading works and expansion works and repair works and renovation works.

Upgrading works focuses on enhancing building performance, efficiency and safety by modernizing electrical systems and adding environmentally-friendly air-conditioning and security system updates (Chiara et al., 2024). Expansion works consist of building extensions which both enhance the operational capabilities and improve functional efficiency of existing structures. Repair works entails structure restoration together with mechanical and electrical system repairs. Renovation works consist of building upgrades through structural and non-structural modifications to fulfill new requirements.The main objective of restoration is to retrieve heritage buildings into their former condition while maintaining their genuine historical designs.

Current Industry Context

Over budget and unexpectedly high or increase of refurbishment costs are prevalent issues in Building Refurbishment Projects (BRPs) worldwide, particularly in Malaysia. These financial challenges have been increasingly observed, highlighting a significant concern for stakeholders involved in refurbishment projects. The unpredictable nature of costs often stems from various unexpected issues, such as structural modifications, hidden defects, and the complexities of integrating modern building technologies into existing structures.

Budgeting is a crucial consideration in measuring the success of a refurbishment project. Effective financial management directly influences project outcomes, as exceeding budget constraints can lead to project delays, compromised quality, and client dissatisfaction. Understanding and studying the factors that affect budget efficiency in BRPs is essential for developing strategies to mitigate these risks.

Despite the increasing number of refurbishment projects in Malaysia, the associated risks and uncertainties remain inadequately addressed. As noted by previous research, managing BRPs involves navigating a myriad of challenges that encompass technical, legislative, ecological, and social considerations (Ali et al., 2008; Rahmat and Ali, 2010). Without a thorough examination of these factors, it is difficult to develop effective financial management strategies that enhance budget efficiency and ensure the successful completion of refurbishment projects.

This study aims to identify the key factors influencing budget efficiency in BRPs and explore effective financial management strategies from the contractors' perspective. By addressing these issues, the research seeks to contribute valuable insights that can help improve the overall success and sustainability of refurbishment projects in Malaysia.

The Progress of BRPs in Malaysia

The number of BRPs in Malaysia has expanded notably throughout recent times because of modernization needs alongside expansion requirements and maintenance requirements and environmental protection needs.

Table 2.1 Number of Building Refurbishment Projects (BRPs) in Malaysia by Type (2019–2022)

Type of Refurbishment Works	Number of Projects			
	2019	2020	2021	2022
Upgrading	520	478	512	589
Expansion	380	329	378	462
Repair	285	275	295	310
Renovation	265	254	278	325
TOTAL	1450	1336	1463	1686

Table 2.1 demonstrates a substantial upward growth pattern spanning from 2019 until 2022 specifically within the scope of upgrading activities as well as expansion projects and repair works and renovations. BRPs activities in Malaysia have experienced substantial growth because of modernization trends together with expansion needs and maintenance requirements and environmental considerations.

a.Sustainability and Green Building Practice

The Green Building Index (GBI) launched in 2009 achieved 619 certifications for sustainable buildings up to 2022 (Ha et al., 2023). Organizations implement sustainable technology to minimize expenses as well as comply with ESG principles (Kasim et al., 2021).

b.Technological Advancements and Changing Market Demands

The construction industry focuses on three main renovation trends involving intelligent home systems and green building materials alongside better ventilation technologies (CIDB, 2024; Joseph, 2023; RumahHQ, 2024; TRUX, 2024) because customers increasingly want sustainable efficient buildings.

c.Preservation of Heritage Buildings

Heritage buildings essential to Malaysia's national culture must undergo restoration according to the National Heritage Act 2005 (Fauzi & Ghani, 2022). There exists an ongoing conflict between maintaining historical sites while fulfilling the needs of modern-day functionality. Therefor reserving heritage buildings is a key trend shaping BRPs in Malaysia. This trend aligns with global efforts to include heritage preservation in modern urban planning and development.

Funding of BRPs in Malaysia

BRP funding depends on public support, private support or a combination. Government leads public projects developing infrastructure (Mohamed et al., 2023). Private foundations finance property improvement projects (Liew et al., 2022).

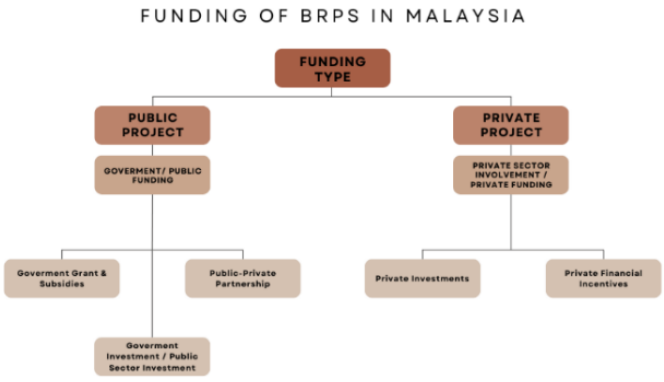


Figure 1.0 Funding Type of BRPs in Malaysia

Figure 1 Funding Type of BRPs in Malaysia illustrate the financial support for this type of development comes from government agencies and financial institutions together with private investors. Government investments together with grants and subsidies form the basis of public funding which can be combined with public-private partnerships (PPPs) as an avenue to share financing and assume risks (King & Wood, 2024). Private organizations

use investment capital from firms together with individual funding which frequently benefits from tax advantages specifically for green initiatives (MIDA, n.d.)

Challenges in Refurbishing Existing Buildings

BRPs creates better urban environments as well as preserves cultural heritage while encountering barriers from financial restrictions and technical problems as well as regulatory issues and sustainability concerns and social impact obstacles (Simona et al., 2018).

a.Financial Challenges

Building operations face financial burdens when specialized materials and skilled labor and unanticipated structural problems emerge (Sayce et al., 2017; Lee & Smith, 2020).

b.Technical Challenges

Older buildings brings difficulties due to weak foundations coupled with outdated construction techniques and the absence of historical documentation records. Implementing contemporary materials and technology poses complex challenges because of compatibility disputes according to Ali and Hashim (2018) and Rahman et al (2020) along with Tan and Lim (2019).

c.Regulatory Challenges

Following modern building codes proves challenging when preserving heritage buildings because it becomes necessary to find stable solutions for matching preservation needs with structural improvements.

d.Sustainability Challenges

The poor energy conservation standards of older buildings create financial burdens for complex and intricate modernization processes. Refurbishment activities create waste that leads to environmental concerns according to Chong & Lee (2018) as well as Ng et al. (2021) and Mohamed et al. (2020).

e.Social Challenges

Building renovation leads to disturbing sounds along with restricted building entry points and interferes with the living conditions of building residents. Building owners operate alongside contractors together with government agencies to handle renovation projects which introduces various challenges (Cheah & Tan, 2019; Rahim et al., 2022).

Budget Control in BRPs

Understanding Project Budget and Budget Control

Project budgets predict all necessary expenses throughout project completion (Kerzner, 2022). A project budget divides funding resources between direct costs and indirect costs. Direct costs comprise of three main elements: labor, materials and equipment. A site office with its supporting administrative functions along with related general expenses fall under indirect costs according to MEB Total (2024).

Budget control checks financial spending within defined limits (Chitkara, 2019). Budget control systems ensure active project spending monitoring and stages-based budget changes from development start to finish. Budget control systems provide complete frameworks for controlling complex projects as noted by PMI (2021). The financial operations require both budgeting and budget control as the essential tools to bring results. Budget control systems establish necessary financial decision making tools that minimize project risks and generate better results (Müller et al., 2019).

The Technique of Budget Control in Construction Projects

Keeping construction projects within budget is an important goal of project management. This is especially true for building refurbishment projects (BRPs), which often have special challenges. There are several techniques that can help manage costs and keep projects on track.

a. Precise Budget Estimates

Budget planning should include additional funds for unpredicted costs (Deltek, 2024). Thorough cost estimation minimizes budget expansion (Love et al., 2018).

b. Accurate Project Schedule

A structured timetable enables both quality performance and financial objectives to be achieved before deadlines. Regular updates prevent delays. The progress of projects gets monitored along with plan implementation through the use of project management tools (PPM Express, 2024). =

c. Improved Team Communication

Proper communication methods help avoid misinterpretations thus stopping delays from occurring. Continued project communication maintains a clear picture of budget utilization in addition to ongoing progress status (Bauwise, 2024).

d. Smart Procurement Strategies

Smart procurement strategies can help control costs and improve project efficiency. This includes negotiating better terms with suppliers, buying materials in bulk to take advantage of discounts, and selecting affordable yet quality options. Careful procurement management can cut project costs by up to 15% (Love et al., 2018).

e. Daily Reports and Regular Updates

Regular tracking of expenses helps spot financial problems early (Deltek, 2024). Using digital tools, such as project management software, makes it easier to create reports and share updates with everyone involved (PPM Express, 2024).

f. Backup Plans

Unexpected problems can raise costs. Contingency funds enable support for additional expenditure (Deltek, 2024). Regular review of backup plans maintains continuous progress according to CFAJournal (2024).

g. Reliable Subcontractors

Strong relationships with subcontractors present lower prices (Bauwise, 2024). Performance review processes at established intervals enable organizations to prevent expense-raising project delays (Arditi et al., 2005).

h. Effective Change Order Management

Cost overruns can be avoided through documented budget approval (Reqi, 2023). Specialized software enhances precision and automated tracking of the project (Jennifer, 2023). Effective change management practices enable the achievement of budget and schedule goals during projects (CIOB, 2021).

The Importance of Budget Control for Project Contractors

Budget control stands as an essential fundamental element which leads construction projects to their objectives of success. Budget control emerges as a crucial element when you balance correct project planning with proper financial resource management.

Organizations require strict budget control systems primarily because of their need for financial stability. As contractors maintain multiple on-going site projects at once they need exceptional abilities to monitor their financial operations. The practice of professional budget management provides contractors with more extended periods of financial stability based on Kerzner (2022).

Project management success acts as an essential motivational factor for managers to accomplish their mission. Proper budget control allows contractors to use budgeted funds strategically which decreases the likelihood of exceeding the budget. Organizations conduct regular expenditure reviews to verify if money is being utilized as budgeted. Project budgets fulfill a fundamental role according to Love et al. (2018) because they achieve project success and reduce customer anxiety while improving satisfaction rates.

Financial risk management can be achieved through budget control systems. The execution of construction projects typically deals with three main challenges such as delays together with price changes and site issues. The regular practice involves reserving 5-10% of total budget as contingency funds (Deltek, 2024). Detecting and solving problems during their early stages represents a major advantage given by budget control systems.

Project success happens only when project expenditures stay within the approved budget allocations. Buildings under construction performed by contractors with excellent budget control capabilities achieve on-time completion and maintain project quality standards according to Müller et al. (2019).

Reputation is important in construction. Contractors who successfully execute their tasks both financially sound and budget-compliant gain a position as dependable professionals. Prospective clients keep working with trustworthy contractors who execute their tasks within budget thus obtaining more contracts. Financial responsibility functions as an organizational strength which develops trust between clients as well as suppliers and business partners according to Arditi et al. (2005).

A well-controlled budget enables contractors to gain market superiority. Constructors with excellent cost control skills can maintain their profits and provide competitive prices as a result. Factoring effective budget control enables organizations to obtain higher profit margins together with new client acquisitions (Jennifer, 2023).

Clients show higher satisfaction when contractors fulfill their budgetary requirements. Contractors with good budget management gain client trust and future work. Companies that make clients happy receive both new business from referrals and gain repeat opportunities (Bauwise, 2024).

The control of budgets enables organizations to achieve sustainable future expansion. Budget control among contractors enables money reinvestment into business development while also enabling technology adoption and business expansion (CIOB, 2021). Effective financial health exists because of budget control which leads to business sustainability.

Organization of budget resources serves as an essential condition for maintaining financial stability together with risk management and delivering project success. The practice provides contractors with tools to remain competitive while developing an excellent business reputation and expand their operations.

C. *Causal Factors Contributing to Difficulties in Controlling Project Budget in BRPs)*

The Difficulties of Budget Control for BRPs

Budget control within BRPs faces multiple significant barriers that impede project implementation progress. Budget unexpectations develop when project design changes and price inflation occurs together with improper forecast calculations which create budgetary tensions. Project implementation delays occur because funding delays combine with resource distribution problems to create wastage of workforce and materials along with equipment. The necessity for regulatory compliance implementation makes budget preparation more complex because financial planning becomes burdened by alterations in policies and financial regulations. Panels dealing with poor financial reporting struggle to make swift decisions while imprecise budgeting forces agencies to confront monetary obstacles. Project delays together with escalating costs regularly occur after stakeholders disagree about contractual terms according to Jones et al.(2021) and Smith & Brown(2022).

Causal Factors Contributing to Budget Control Challenges

The control of project expenses in refurbishment projects (BRPs) faces multiple concerning barriers. The key factors are:

a. Financial Constraints

Large upfront investments needed for refurbishment projects put extensive strain on the project's funding at the beginning. Rehabilitating outdated constructions proves more costly than constructing brand-new facilities because of their age-related modifications. Project budget suffers from limited funds that force compromises either to project quality standards or scope delivery.

b. Unforeseen Issues

Structural problems that hide during the refurbishment process reveal themselves unexpectedly thus producing additional expenses. The implementation of new building codes and regulations forces project designers to make expensive modifications.

c. Complex Stakeholder Management

Budget control becomes difficult due to many stakeholders involved including owners and contractors together with regulators.

d. Scope Creep

Additional demands for fresh features and unexpected problems leading to project scope enlargement which creates additional financial costs.

e. Market Volatility

The budget gets impacted by the market-driven changes in materials prices along with labor rates.

f. Technical Challenges

The implementation of modern materials alongside old structures demands specialized technical knowledge that incurs high expenses.

g. Sustainability and Environmental Concerns

The integration of sustainable materials combined with energy-efficient systems requires investing more money at the initial stage therefore stretching the available budget.

Several elements make it hard to administer budgets in BRPs.

D. *Mitigating Actions to control project budget in BRPs*

Effective Planning and Budgeting

Early project scope definition combined with precise cost estimation helps prevent budgetary overruns and unforeseen additional expenses (Chen et al., 2020; Love et al., 2019). Project Management Institute (2023) shows that risk assessments performed in advance enable teams to spot potential money-related problems.

Stakeholder Engagement and Communication

Stakeholders who receive accurate information throughout the project development minimize errors which reduce the need for unnecessary changes (Zhang et al., 2021; Olaniran et al., 2022). The process of supplying routine development reports and matching stakeholder aims to financial targets minimizes expense growth (Hwang et al., 2020; Zhang & Choi, 2018).

Monitoring and Control Systems

The continuous process of budget monitoring helps spot financial problems at an early stage according to Wong et al. (2022). Real-time cost monitoring through BIM and Earned Value Management (EVM) tools provides necessary data to make prompt corrective decisions according to Alwi & Hampson (2020) and Niazi & Arshad (2020).

Stakeholder Engagement and Communication

The ability of teams to respond immediately to hidden structural flaws or regulatory changes protects construction projects from budgetary issues (Durdyev & Hosseini, 2020; Project Management Institute, 2023).

Procurement Strategies

Competitive procurement and tendering methods create opportunities for businesses that deliver optimal value at reasonable prices hence lowering budget risks (Memon et al., 2018). Additional cost efficiency results from implementing value engineering within design stages of construction projects without sacrificing their quality standards (Clevenger & Haymaker, 2021).

III. PROPOSED METHODOLOGY

A. Research Methodology

The study relies on qualitative research to fulfill its research objectives. Qualitative research through interviews collects detailed information from contractors who have worked in BRPs.

Research Process

The research process involves the following steps:

a.Topic Selection: Focuses on challenges faced by contractors in managing budget control during BRPs.

b.Literature Review: Revealed common issues such as cost fluctuations due to structural deterioration, unexpected regulatory changes, and inaccurate project scope definitions.

c.Research Objectives: The objectives are to identify and understand the main challenges faced in budget control during BRPs, the reasons, and the strategies contractors employ to manage them.

d.Research Questions: The study addresses key questions regarding the causes of budget issues and the strategies used by contractors to mitigate or address these challenges.

e.Methodology Choice: Qualitative approach selected for in-depth exploration of contractors' experiences and strategies in budget management.

f.Data Collection: Semi-structured interviews are conducted with contractors involved in BRPs, either in person, online, or through messaging platforms, allowing for flexible and detailed responses.

g.Data Analysis: The collected data is analyzed using thematic analysis, identifying recurring themes, challenges, and solutions, with insights categorized under key issues and strategies.

Research Approach

A qualitative research method serves to understand human actions together with their experiential aspects. Through this approach the research achieves comprehensive understanding about budget control practices used by contractors in BRPs. Semi-structured interviews serve as the main data collection method in this project to retrieve detailed adaptable information.

B. Data Collection Technique

Semi-structured interviews serve as the main approach to collect data. Contractors have been chosen for this technique because the method allows them to provide detailed first-hand information about their budget control experiences. Interviews enable relevant follow-up questions which make it possible for researchers to obtain in-

depth information about the difficulties that contractors experience.

C. Sampling Method

A non-probability sampling approach was more appropriate. The research follows purposive sampling by choosing contractors with minimum three years of experience or finish at-least one Refurbishment Projects. These qualified respondents have sufficient knowledge and experience to deliver important and relevant information regarding BRP budget control challenges.

D. Data Analysis

The investigation of budget control practices in BRPs uses thematic analysis to identify patterns within qualitative data. The research methodology consists of six sequential phases starting from data familiarization and continuing to code important segments before organizing similar codes into larger themes until the researcher validates themes against accuracy standards. Budget control analysis becomes more efficient using NVivo software because it helps users organize data and code information as well as show patterns.

E. Reliability and Validity

The reliability of data collection methods remained consistent because all participants answered standard interview questions. A pilot test operated to refine questions that were not clear thus improving the clarity and consistency of the data. The researchers recorded the interviews and transcribed them while multiple researchers individually coded the transcripts to establish interpretation consistency. Three methods were used to improve validity: first by comparing data from interviews to existing studies, having participants check the transcripts, and implementation of peer review and comprehensive descriptions of research background and findings. The research design includes these procedures to improve its reliability and validity.

CONCLUSION

This paper has examined the key factors contributing to budget control challenges in building refurbishment projects (BRPs), including unforeseen structural issues, regulatory changes, scope creep, and market volatility. Through a synthesis of existing literature, the study identifies critical mitigation strategies such as proactive risk management, stakeholder engagement, and adaptive procurement approaches. The discussion highlights the need for contractors to balance flexibility with rigorous financial oversight when managing refurbishment projects. While this paper establishes a theoretical foundation for understanding budget control in BRPs, future empirical research is needed to validate these conceptual frameworks in practical settings. The insights presented aim to inform both academic discourse and industry practices, ultimately contributing to more effective financial management in sustainable building refurbishment.

ACKNOWLEDGMENT

The author acknowledge the guidance and supports provided by the supervisor, Assoc. Prof. Dr. Nazirah Binti Zainul Abidin from Universiti Sains Malaysia, Pulau Pinang, Malaysia.

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UNVEILING SUCCESS FACTORS OF STRATA WAQF DEVELOPMENT: EVIDENCE FROM PENANG

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ABSTRACT

The Strata Waqf Scheme is an innovative approach to waqf properties owned by individuals or organizations under the concept of waqf. Penang is the first state in Malaysia which successfully implemented this scheme. However, the process of developing Strata Waqf Scheme differs from conventional strata schemes due to distinct legal and procedural requirements. The aim of this study is to identify the processes of strata waqf scheme development and factors that influence the success of strata waqf scheme development in Penang. A qualitative study was conducted through interviews with the stakeholders and analyzing with descriptive analysis. The findings of the study found that clear legislation and governance, and economic growth are essential for successful waqf development. Furthermore, economic conditions have a direct impact on the viability of waqf land development, therefore both the public and private sectors must be involved. However, the implementation of strata waqf scheme development remains limited in Malaysia. Given Penang's success, similar development might successfully introduce a strata-based development strategy throughout Malaysia that satisfies the requirements of the population while ensuring a practical and sustainable approach to waqf land.

Keywords: Waqf Development, Waqf Governance, Property Development, Strata Waqf, Success Factor

I. INTRODUCTION

Waqf has played a significant role in the socio-economic development of Muslim societies for centuries, and also serves as a key instrument for sustainable wealth distribution and public welfare. The word waqf originally comes from the Arabic term waqf, which is derived from “waqafa”. Stop, prevent, or withhold are some possible meanings that may be associated with this term. In Islamic law, the term waqf refers to the possession of property, its preservation for the limited benefit of charitable contributions, and the prohibition of its use or disposition for purposes other than those stated. According to this definition, waqf is perpetual, meaning that it pertains to non-perishable assets in which the use and rights can be obtained without consuming the asset itself. This can be linked to buildings and land which are often used as waqf property (Kahf, M., 2003, January). Given its enduring nature, waqf development has become an essential mechanism for advancing community infrastructure, education, and social welfare initiatives.

Waqf development is a unique fusion of saving and investing. It works by reducing the use of some resources and repurposing them as productive assets that boost the economy's capital accumulation. According to the waqf principle of perpetuity, an asset may not be sold or otherwise disposed of. It should always be within the waqf's authority. Therefore, waqf properties will continue to grow while also being prevented from decreasing because there is a prohibition on using them or leaving them idle with any kind of neglect, violation, or action. As a result, waqf can be said to be not just an investment; it is also an increasing and cumulative investment (Budiman, M. A., 2014). This practice can produce responsible, helpful, and loving characters, which are things that Islam encourages, from the perspective of waqf growth. Thus, waqf properties need to be developed to meet the objectives of its Islamic application. Waqf institutions, communities, or individuals can all contribute to the development of waqf properties (Abd. Shakor bin Borham, 2003). The research paper will examine the processes of strata waqf scheme development and factors that influence the success of strata waqf scheme development in Penang, Malaysia.

II. STRATA WAQF DEVELOPMENT

A. Waqf Development

Waqf development widely refers to the possession of some property, its preservation for the limited benefit of particular philanthropies, and the prohibition of its use or disposition for purposes other than those specified. In short, it is the process of improving waqf assets to provide benefits while maintaining the property and achieving the donor's objectives (Kahf, M., 2003). According to the Federal Constitution, Ninth Schedule, List II (State List), waqf is posited under state jurisdiction in Malaysia, which has the authority to enact laws related to waqf (Article 74). Selangor (2015), Melaka (2005), Negeri Sembilan (2005), Perak (2015), and Terengganu (2016) are the only five states that have passed particular waqf laws thus far (Federal Constitution of Malaysia, Ninth Schedule, List II, Article 74). The Yang di Pertuan of the State is the highest authority on Islamic matters in Federation states like Sabah, Sarawak, Malacca, and Penang that do not have a governing body (Wu, 1991). In other states, waqf concerns are referred to the State Islamic Religious Councils (henceforth referred to as SIRC) (Hj Mohd Salleh and Muhammad, 2008).

The potential for development of 254,157 acres of waqf land is evidence of Penang Waqf's substantial and plentiful assets, and the Strategic Development Plan Phase 1 (which takes ten years) also presents strategic development proposals (Wakaf Pulau Pinang-backup – Wakaf MAINPP. , 2025). In order to protect the welfare of the ummah by providing physical infrastructure and services in the areas of religion, education, health, agriculture, and commerce, as well as by protecting the welfare of the less fortunate, Malaysia, an Islamic nation, is actively involved in the planning and implementation of the waqf property development plan (Asmak Ab. Rahman, 2009:136-44). The waqf manager, who is typically referred to as *Mutawalli*, *Nazir*, or *Qayyim*, is responsible for managing the waqf property in the beneficiaries' most beneficial way. *Mutawalli's* primary responsibility is to protect the property, which is followed by maximizing the beneficiaries' income (Kahf, M., 2003). One notable instance of waqf development in Malaysia is the establishment of Madrasah Al-'Attas in Johor Bahru in 1914 by Habib (sayyid) Hassan al-'Attas, one of the most well-known Arabs, who was instrumental in the establishment of numerous Arabic schools in Malaya ("Tunas Melayu," cited in Othman, 2006). Numerous academics, politicians, lecturers, and officials have come from Madrasah al-Attas. As an international example, the first mosque in Malacca, Omar Kampong, was established in 1826. It was the first waqf established in Singapore by Mr. Syed Omar Al-Junied, an Indonesian businessman and philanthropist who most likely came from Yemen in 1820 (Ibrahim, 1965).

Success Factors of Waqf Development

The effectiveness of waqf development depends on a number of factors. According to Shukor, A. S. A. A. (2015), one of the key elements in guaranteeing the physical growth of waqf assets is the waqf management factor, as inconsistent administration and management will lead to disputes over waqf asset management (Abd Malib, M., Markom, R., & Abd Rashid, R. , 2015). Furthermore, one of the factors is a significant financial factor, which is necessary for waqf development to be successful in overcoming financial obstacles. Among them, Khoo (1980) wrote about the Sultan Zainal Abidin University (UniSZA) which was constructed on waqf property granted by specific parties. In an attempt to speed up the transformation of productive waqf into one which is more effective, efficient, and transparent, technological use in waqf is useful to collect and administer waqf through the use of technology and digital platforms (Rahmawati et al., 2021).

Waqf development success is largely dependent on the interaction of effective waqf management, long-term financial viability, and technology use. Good management not only makes transparent governance and effective budgeting easier, but it also boosts donor confidence, which in turn encourages larger financial donations. Simultaneously, the use of technology improves data management, monitoring, and reporting systems, which increases the effectiveness of management procedures. Digital platforms also make it possible for more extensive outreach and more successful fundraising techniques, both of which support the waqf projects' financial sustainability. As a result, the combination of these three elements produces a synergistic effect in which each one supports the others, ultimately promoting the best possible development and use of waqf assets. The summary of this subchapter highlights three critical success aspects for waqf development namely the technological application, financial sustainability, and efficient waqf management.

B. Strata Waqf Development

This development was initially implemented in Penang, but it quickly gained acceptance and spread to neighboring states like Perak and Terengganu, demonstrating the model's enormous potential to boost the sustainable and strategic use of waqf assets. Strata waqf development is an approach of turning waqf land into

multi-unit structures, with the underlying property remaining waqf while individual units (strata titles) are managed or leased. By allowing the vertical construction of residential apartments, business buildings, and office spaces on waqf property, this strategy maximizes the economic potential of scarce waqf assets, especially in urban regions (Ismail, C. Z. et al, 2021). Vertical development refers to stratified development that has been developed by the Penang Islamic Religious Council on several waqf lands. By allowing for flexibility in both income production and usage, strata waqf allows the intended beneficiaries of the waqf to earn a steady income through the sale or rental of strata apartments (as permitted by Shariah) while maintaining perpetual ownership of the land (‘ayn). Additionally, it facilitates greater integration into urban planning and effective asset management, particularly in land-constrained areas (Bahari, Z & Mat Hassan, S.H., 2017).

There are now five strata waqf developments in Penang that have been constructed successfully which are Taman Wakaf Seetee Aisah, Pangsapuri Wakaf Seetee Aisah, Pangsapuri An-Nur Wakaf, Pangsapuri Wakaf Mohamed Hashim, and Pangsapuri Wakaf Khan Mohamed (Department of Director General of Lands and Mines, 2025). The Pangsapuri Wakaf Khan Mohamed in George Town, which comprises 32 parcels and was listed in the parcel schedule on April 25, 2011, was the first Waqf Strata Development recorded. The most recent project is the Pangsapuri Wakaf An-Nur in the North Seberang Perai District, which comprises 120 parcels and was included in the parcel schedule on November 28, 2024 (Department of Director General of Lands and Mines, 2025). By the increased development, it is proven that investors are drawn to these projects because they are all situated in neighborhoods that are close to public facilities and other residential areas. The strong demand for these strata units has encouraged investors to lease units on the waqf land, resulting in the economic success of these strata waqf projects and a favorable effect on the waqf development as a whole. This development was initially implemented in Penang, but it quickly gained acceptance and spread to neighboring states like Perak and Terengganu, demonstrating the model's enormous potential to boost the sustainable and strategic use of waqf assets.

III. METHODOLOGY

A research methodology refers to a set of methods used in the implementation of a research to ensure that the data obtained is valid, accurate and relevant to the study’s objectives. In this research, a qualitative approach was chosen as the main method, given the nature of the study that requires in-depth study of issues and views of various parties. Research data was obtained through a combination of primary and secondary data. Primary data was collected through semi-structured interviews, while secondary data was obtained from sources such as academic literature, official government reports, news articles, and previous case studies. The use of secondary data helped to strengthen the findings from the interviews and provide a comprehensive picture of the implementation of strata waqf development. Semi-structured interviews were chosen because this approach is flexible and allowed researchers to respond to new information that may arise during the interview session. This format allowed researchers to ask prepared questions and encourage respondents to share their views openly, thus producing in-depth and information-rich qualitative data. This approach was very effective in understanding the process of developing the strata waqf scheme and the success factors influencing the strata waqf scheme in Penang. The study respondents consisted of officers at the Penang State Islamic Religious Council (MAINPP) since they were the ones who proposed this project. Table 1 shows the list of respondents who were interviewed, and each respondent will be labeled according to a specific code to facilitate the data analysis process later.

Table 1: List of Respondents

Respondent	Designation	Company
R1	Officer	Penang Land and Mining Office
R2	Senior Assistant Director	Penang Land and Mining Office
R3	Head of Strategic, Development & Compliance Division	UDA Holdings Berhad
R4	Assistant Vice President 2 Sales & Marketing Department	UDA Holdings Berhad
R5	Business Development and Investment Unit Officer Real Estate	Waqf Land Development Division of the Penang Islamic Religious Council

IV. RESEARCH FINDINGS AND DISCUSSION

The process of a Waqf Strata Development needs to follow certain procedures and success factors of Strata Waqf Development involved. To enable waqf property to not only achieve its religious and philanthropic goals but also to sustainably and Shariah-compliant support economic development and social welfare, proper planning and cooperation are crucial.

A. Strata Waqf Development Process

Strata Waqf Development follows the same steps as convectional strata development, which include preparing a parcel schedule, obtaining a Planning Permission (KM), and getting the Certificate of Proposed Strata Plan (CPSP) approved as in Figure 1. Strata Waqf Development differs from conventional strata development, nonetheless, due to a number of particular circumstances. According to Section 14A of the NLC, this development prohibits both sale and buy transactions as well as any transfer of property ownership. Only Muslims have the right to lease land (Section 15A of the NLC), and waqf land cannot be mortgaged. According to R3, the lease offered has a 99-year term, and any loan financing (end financing) must adhere to the *Ijarah*-based Islamic financing concept.

The strata lease concept is used in three waqf land developments. Pangsapuri Wakaf Mohamed Hashim, Pangsapuri Wakaf Khan Mohamed, and Pangsapuri Wakaf An-Nur are the names of these apartments. Building construction has already been finished by these three schemes. However, strata titles are only granted to Pangsapuri Wakaf Mohamad Hashim and Pangsapuri Wakaf Mohamad Khan. Pangsapuri Wakaf Mohamad Khan's building subdivision was based on the previous version of the Strata Titles Act 1985, which was amended by the A1450 Act in 2015. In contrast, the SiFUS approval of the Pangsapuri Wakaf Mohamad Hashim project took longer to approve because it was discovered that the building plan and planning permission needed to be revised numerous times to comply with Waqf principles.

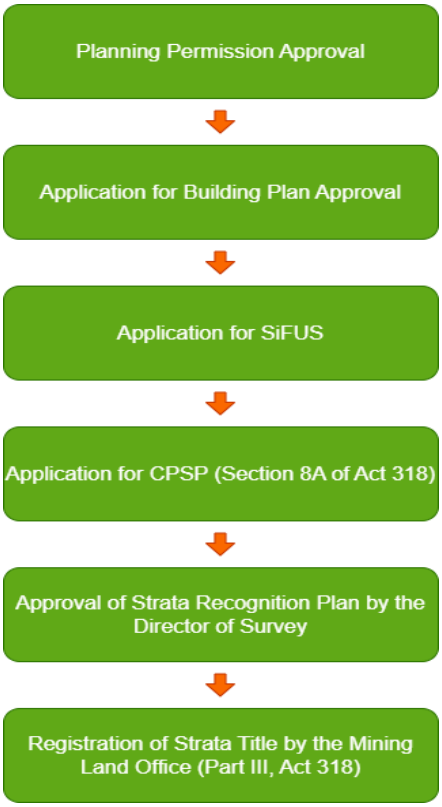


Figure 1.0 The Development Process of Strata Waqf Development
Source: Penang Land and Mines Office (2025)

According to R2, the procedure for acquiring a strata waqf development in Penang is similar to strata scheme development, as shown in this flowchart. In accordance with Section 21, Act 172, the first steps in the procedure are the appointment of a Licensed Land Surveyor (JTB) and the obtaining of Planning Permission (KM). The

building plan is approved if there is a stratum scheme included in the development. Following approval, an application for workbook and lot numbers is submitted along with a deposit for the survey price. A Parcel Schedule is next created, and the Certificate of Share Unit Formula (SiFUS) application is submitted. The Parcel Schedule is submitted to the Commissioner of Buildings (COB) when it has been approved. If approved, parcel sales can start while the superstructure stage of construction is ongoing. When the developer reaches the superstructure stage, they apply for the Certificate of Proposed Strata Plan (CPSP) under Section 8A, Act 318, and notify the Land and Mines Office (PTG). An application for strata title (Section 9, Act 318) is filed after the authorization of CPSP, together with the necessary paperwork and funds. After the State Director (PTG) and the Director of Survey analyze the application, JUPEM prepares the strata title plans. PTG's registration of the strata title is the last step, which results in the owners receiving vacant possession. In strata waqf development, this procedure is crucial since it permits legal supervision of multi-unit waqf buildings while protecting the waqf land.

B. Success Factors of Strata Waqf Development

Strata Waqf Development success is based on a number of interconnected factors that impact the development's sustainability, efficiency, and Shariah compliance. These elements ensure that waqf properties are developed in line with Islamic law while also promoting long-term value development, social well-being, and economic growth.

1. Governance and Waqf Management Factors

The Penang State Islamic Religious Councils (MAINPP) are in charge of waqf management and administration. As the only trustee of waqf property, MAINPP certainly faces a number of difficulties in managing it, particularly when other parties' cooperation is required according to R1. Effective governance is crucial to guaranteeing that all parties fulfill their obligations in a responsible, transparent, and effective manner. The socio-economic aspects of the Islamic ummah can be developed by efficient waqf management and administration.

i. Agency's Goals

R3's interviews indicate that the objectives and intentions of the organizations engaged in waqf strata development contribute to the development's success. The sincerity and dedication of the agency in advancing the needs of the ummah, particularly to strengthen the Bumiputera economy, are critical to the success of a waqf initiative. The project's sustainability will be enhanced by having specific objectives including raising money for more development, increasing the community's advantages from waqf, and providing Muslims with a model of effective waqf management. Additionally, agencies are motivated to behave with more accountability and honesty by the need to satisfy religious requirements and maximize the potential of waqf land.

ii. Stakeholder Involvement

According to R3, the term "entities" describes organizations or people who are either directly or indirectly involved in the creation of waqf and the development of strata waqf. They include the Penang State Islamic Religious Council, which serves as the waqf trustee, real estate developers with experience in building strata projects, local authorities (PBT), who are involved in approving and regulating, the Ministry of Housing and Local Government (PKPT), and the local community, who receive waqf benefits and provide social support. The ease and success of a waqf development project are determined by how well various entities collaborate, which makes it crucial.

iii. Resilience and Consistency

The Strata Waqf Development is a lengthy and complicated process, so the Patience Factor (Resilience and Consistency) is crucial to its success. The legal and approval procedures frequently take a lengthy time, particularly when multiple agencies are involved and sharia and civil laws must be followed. Furthermore, according to R3, it typically takes a few years for waqf projects to yield a return on investment, which calls for patience from all stakeholders, including waqf institutions, developers, and beneficiary communities.

2. Economic and Property Market Factors

According to Datuk Seri Dr. Mohd Uzir Mahidin, Malaysia's Chief Statistician, Penang is expected to expand by 3.3 percent in 2023. Penang has had tremendous economic, social, and infrastructure development and is a major hub for trade and tourism in the northern part of Peninsular Malaysia. Numerous domestic and foreign investors have been drawn to this development in order to invest in and develop properties in key locations

including George Town, Bayan Lepas, and Seberang Perai. Land values in Penang have sharply increased as a result of this circumstance, particularly in urban and industrial regions.

i. Strategic Location

One of the primary factors is location, which includes how easily accessible basic utilities like roads, public transportation, other social amenities are and the size of the land. These factors have a direct impact on the potential and value of growth. Furthermore, it is crucial to do a feasibility study in order to evaluate the project risks, development expenses, and possible returns prior to execution. Another consideration is land zoning, which is how local governments categorize land use. Certain waqf land may only be used for agriculture and cannot be used for residential use unless the condition conversion process is completed. In order to ensure that strata waqf projects can be used as efficiently as possible and yield long-term returns, economic and real estate market elements such as land status, development costs, and strategic location must be considered.

ii. Increased in Demand

The Strata Waqf Development's success is also determined by the demand factor, as the project's sustainability and returns are influenced by the degree of demand for the built property units. This demand is influenced by a number of factors, including the local population density, consumer spending power, and the demand for particular property kinds in the neighborhood. There is a higher chance that the units will be sold or rented if the project is built in a high-demand neighborhood, guaranteeing a steady income flow. However, a low level of demand could result in an excess of unsold units, which would strain the waqf institution's finances. According to R2,to ensure that the waqf land is used efficiently and continues to serve the community, a thorough market demand analysis must be conducted prior to beginning development.

iii. Financing and Investment Climate

Since Strata Waqf Development depends on having enough capital and funds, financing and investment climate is a major determinant of its success. A key factor in guaranteeing the sustainability of development is the availability of Islamic financing or other funding sources for waqf projects. The *Tabarru'* scheme, a type of voluntary contribution or donation made without anticipating a return and utilized for welfare and public benefit initiatives like waqf development, is one of the funding options. At the moment, the *Tabarru'* program is only available through three significant financial institutions: Bank Islam, Bank Muamalat, and Bank Rakyat. However, Maybank has lately shown interest in joining this program, indicating the possibility of expanding waqf project funding sources. Development potential is also influenced by investor confidence and money availability, as long-term sustainability and competitiveness are enhanced by ventures with strong financial backing. Thus, a favorable investment environment and a range of Islamic financing choices are crucial factors in the development of strata waqf, according to R3.

CONCLUSION

In summary, the strata waqf process offers an exciting strategy to maximizing the potential of waqf land through planned and systematic development. However, a number of crucial enablers are necessary for its successful implementation. The success factors include efficient waqf management, financial sustainability, and technological application, which all contribute to the successful implementation and long-term impact of waqf projects. These elements not only make waqf development more operationally feasible, but they also help move away from traditional waqf methods and toward more creative models like strata waqf. The results show that in order to guarantee that waqf assets are developed effectively, openly, and in ways that benefit the larger community, it is essential to handle these concerns comprehensively.

The impact of the implementation of this strata waqf development is very positive, as it not only generates multiple returns to the waqf through leasing, but the funds can also be used to develop more waqf land in other locations. Furthermore, the selection of strategic locations and high demand for strata units make this development competitive and competitive in the current property market. Overall, strata waqf development is a sustainable, shariah-compliant development model, with great potential in empowering the Muslim economy in the long term.

ACKNOWLEDGMENT

This research paper would not have been possible without the outstanding support of several people, including the supervisor and the respondents (the collaborator agency, the land administrator, and the Penang State Islamic

Religious Council). The passion, expertise, and dedication to detail have inspired and kept the work on track to the end. Those who have contributed to this research are also respected and appreciated.

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THE IMPACT OF TECHNOLOGICAL INNOVATION ON INSTITUTIONAL INVESTORS' DECISION-MAKING: DATA ANALYTICS IN OFFICE BUILDING

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ABSTRACT

Innovation in technology has become a cornerstone of transformation in all industries, including real estate investment. The technologies such as Data Analytics, Artificial Intelligence (AI) and Machine Learning (ML) have impacted on the real estate investment decision-making processes. In recent years, advantages in data analytics have transformed how institutional investors make decision in complicated market such as office building investment. This study explores how data analytics reshaping decision-making processes for institutional investors in office building investments. While data analytic help investors in enhancing risk prediction, accurate valuations, and enabling data-driven strategies, they remain underutilized primarily due to risk aversion and a continue dependence on traditional investment approaches. Moreover, existing information databases are of varying quality, lack transparency and inefficiency. The aim of this study is to explore the role of data analytics in influencing institutional investors' decision-making processes regarding office building investments. The first objective is to understand how data analytics influence the decision-making of these investors. The second objective is to examine how data analytics impact risk management strategies in office building investments. The study utilizes a qualitative approach by integrating a comprehensive literature review with structured interviews conducted with real estate professionals. Findings from this study have shown that the real estate professionals that integrate emerging technologies into their real estate frameworks achieves higher returns and streamlined risk management. However, the adoptions of these technological innovation still remaining low due to the adoption barriers.

Keywords: Technological Innovation, institutional investors, data analytics, office building investment

I. INTRODUCTION

Technological innovation has significantly enhanced efficiency, flexibility, and adaptability within industrial practices (Starr et al., 2021). Tools such as data analytics, artificial intelligence (AI), and machine learning (ML) have enabled investors to more accurately predict the real estate investment environment. Yang (2024) finds that advanced AI and ML models significantly outperform traditional statistical methods in forecasting market trends across regions and property types. This predictive power enables investors to optimize strategies, gain competitive advantages and led to measurable cost savings and better client outcomes.

Despite these proven advantages, the adoption of such technologies remains limited. Researchers in the real estate and construction sectors highlight that many investors and practitioners still lack a sufficient understanding of data-driven tools. For instance, Regona et al. (2022) noted that technology acceptance is rather limited and points to a clear knowledge gap regarding the causes of low adoption.

In addition to knowledge barriers, practical and technical challenges further constrain adoption. AI systems typically require large, high-quality datasets and involve high initial costs that many firms are unable to absorb (Regona et al., 2022). Consequently, even robust algorithms may fail to deliver value when implementation costs are prohibitive or site conditions are unpredictable. Moreover, many large firms continue to rely on traditional investment methods (Tanrivermiş et al., 2024). Even those open to innovation often revert to familiar practices. Reviews indicate that institutional inertia persists, with companies depending on traditional processes that could

be automated. These findings underscore a persistent gap between the promise of technological innovation and its practical application.

Finally, the uneven quality, transparency, and efficiency of existing information databases further complicates adoption. The fragmented nature of data in the real estate industry amplifies the uncertainty of investment risks and contributes to data overload and analytical complexity (Hazeem, 2024). Therefore, the integration of technological innovations, alongside improved governance practices, is essential to promote both operational efficiency and long-term sustainability.

Purpose Of Study

This study aims to investigate impact of technological innovation on institutional investors' decision-making process, specifically focusing on the role of data analytics in office building investments.

II. PRELIMINARY LITERATURE REVIEW

In recent years, the incorporation of technological innovations such as data analytics, artificial intelligence, and machine learning transforms the real estate investment decision-making framework. This preliminary literature reviews will be focus on 2 importance topics: (1) data analytics and decision-making in office building investments; and (2) data analytics in risk assessment and mitigation.

DATA ANALYTICS AND DECISION-MAKING IN OFFICE BUILDING INVESTMENTS

Data analytics is an important process in real estate investment decision-making process. Investors can gain necessary tools and insights to assist them navigate the complexities of the real estate market, maximize profitability, and match their investments with sustainability and ethical issues by incorporating data analytics into their real estate investment decisions (Edet, T. U. 2023).

In recent year, technological innovation has introduced a variety of new tools and techniques that are reshaping the property investment landscape. Rather than the traditional investment method that relied on historical data and expertise intuition, the technological innovation has promoted a data-driven investment method that provides a more flexible and resilient investment framework. The shift from traditional method to the data-driven method represent in the in how institutional investors evaluate office building investments. Institutional investors are now able to use a predictive analytics to simulate the volatile real estate market conditions. For instance, the deep learning algorithms model could forecast property value by integrating diverse datasets, including economic indicators, demographic trends, and transactional histories (Zhao et al. 2022). Machine learning techniques help investors make better real estate decisions by enabling computer algorithms to analyses past property sales data and automatically forecast house values. Real estate professional can use the machine learning techniques to analyses sales data as benchmarks and provide a trading strategy.

Same opinion was express by Baldominos et al. (2018), whereby his study emphasis that machine learning algorithms can analyses historical occupancy patterns and macroeconomic indicators to forecast rental yields with 80%–95% accuracy. These algorithms optimize valuation models by iteratively adjusting parameters to minimize error. In addition, machine learning techniques also can identify investment opportunities when the actual price is much less than the expected value. Thus, institutional investors are advisable to use the machine learning techniques to process the vast datasets and reviews several factors such as current market trends, properties characteristics and economic indicators to predict the property value accurately.

Moreover, the machine learning techniques helps investors constantly update property valuations by integrating real-time data such as changes in market demand and supply. However, it is especially true in the office building market where trends such as changing work patterns, the economic cycle and regulatory change mean market conditions can also be particularly volatile. With more data and better analysis, investors can identify new trends sooner and change their models for valuing assets more quickly. This guarantees that their investment choices are in line with the latest market conditions. Organizations fostering a culture of innovation and learning are more likely to adopt advanced analytics for their decision-making processes, thus achieving a competitive advantage in the increasingly competitive real estate environment (Tanrivermis et al., 2024).

As Amicuzi (2024) reports, AI-based systems are being increasingly leveraged to analyze consumer behavior, market trends, and property valuations for investment strategies. Generating AI also helps with decision-making by modeling market scenarios for example how remote work trends would affect urban office demand enabling investors to stress-test their portfolios (Adelusola, 2024). This opens the door for investors to develop more

robust investment frameworks that can adjust to various dynamics. By taking this initiative itself, investors not only enhance the chances to realize higher returns but also gain a strategic advantage in a fast-changing environment.

Data Analytics In Risk Assessment And Mitigation

Every real-estate related investment decision making process requires an in-depth analysis of available information even though it is often carried out in conditions of uncertainty **(Chmielewska, et al. 2020)**. The uncertainty conditions raise the risk of investing in real estate and complicates decision-making. Thus, every investor aims to reduce the uncertainty condition and investment risk to obtain the highest return on real estate investment. Institutional investors are forced to navigate uncertainties tied to market volatility, economic shifts, changing regulations, and real estate-specific elements like location and tenant quality. While the traditional decision making that relied on past market performance does not flexible enough to deal with the volatile real estate market. Therefore, the result of the risk assessment may not accurate and lead to wrong decision making and loss of profits. Technological innovation introduced a more accurate approach to risk managements. The tools such as data analytics, artificial intelligence and machine learning techniques provide a deeper assessment of investments risks and allowed institutional to develop customize mitigation strategies.

Institutional investors can apply the data analytics in risk management for the predictive analytics. The predictive analytics allowed institutional investors to use the real time data to forecast future events. This helps institutional investors to ready and prepare for the potential risk they might be facing in the future. Likewise, **Zhao et al. (2022)** demonstrated that deep learning models could predict market downturns by analyzing a variety of inputs, including economic indicators, transaction histories, and property-specific variables. These predictive capabilities help investors during the decision making process especially in current real estate market that is volatile.

Institutional investors will be able to identify the early warning signals of every possible investments risk by using these technological innovations. According to **Viriato (2019)**, machine learning models can predict fluctuations in office rental rates and occupancy levels by analyzing historical data alongside real-time economic indicators. This proactive approach enables institutional investors to design different contingency plans to mitigate the investment risk such as diversify portfolio and adjusting investment strategies. Institutional investors can use machine learning algorithms to simulate various "what-if" scenarios to customized their own risk management frameworks. **Amicuzi (2024)** and **Adelusola (2024)** add that this will not only improve the predictive accuracy of risk models but also allow for enhanced granularity in risk exposures evaluation. At a more fundamental level, this is an important advancement in assessment for the institutional investor with multiple portfolios across markets and asset classes.

OBJECTIVE OF STUDY

The objectives have been identified as follows:

1. To examine how technological innovations in data analytics influence institutional investors' decision-making processes for office building investments.
2. To analyze the impact of data analytics on risk management strategies in institutional office building investments.

RESEARCH QUESTION AND HYPOTHESIS

This study aims to address the following research questions:

1. How do technological innovations, particularly in data analytics, influence institutional investors' decision-making processes in office building investments?
2. How does the use of data analytics affect risk assessment and mitigation in institutional investments in office buildings?

III. RESEARCH DESIGN AND METHODOLOGY

This research has approached a qualitative method as an appropriate method to explore the technological innovation and its impact on investment decisions. This is because the research uses non-numerical data that are not amenable to counting or measuring. Briefly, this research adopted the following design, which includes 3 phases:

Phase 1: Literature Reviews

A literature review is an evaluation of all available past research related to the field of investigation. The purpose of a literature review is to gain background knowledge of the research topic. The literature reviews will be

conducted by secondary sources such as journals, books, newspapers, technical reports, guidelines and regulations. In addition, the literature reviews will be reviewed on 2 aspects: (1) data analytics and decision-making in office building investments, and (2) data analytics in risk assessment and mitigation.

Phase 2: Interviews
In-depth structured interviews are conducted with real estate professionals to gather expert insights on the practical implications of technological innovation. Two industry practitioners such as property managers or research consultants from leading real estate firms are selected as interviewees. A standardized set of open-ended questions is used to ensure consistency while allowing flexibility for elaboration. The interviews aim to extract rich qualitative data concerning the integration of data analytics and artificial intelligence in investment practices and their perceived impact on decision-making and risk management.

While the small sample size provides detailed and specific context insights, it presents a limitation in terms of generalizability. The findings should be viewed as exploratory and indicative rather than conclusive. Nonetheless, the results contribute to filling practical and knowledge gaps, especially in contexts where empirical evidence remains limited.

Phase 3: Data analysis
The data will be analyzed and interpreted after the interviews by applying thematic data analysis. The audio recordings of the interviews need to be transcribed into written text. Then, the written text needs to be coded, and the code turned into themes. Next, the theme had to be reviewed, defined and named. Finally, the findings are reported using illustrative quotes from interviewees to support each theme and enhance the authenticity of the results. To strengthen the study's impact, particular attention is given to integrating the interview findings with existing academic literature, thereby ensuring that the insights contribute to both scholarly discourse and professional practice.

ACKNOWLEDGMENTS

The main author would like to express his gratitude to Real Estate Department of Universiti Malaya, especially the supervisor for funding this publication.

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STRATEGIES FOR MITIGATING LATE PAYMENT ISSUES OF SUBCONTRACTORS IN MALAYSIA CONSTRUCTION INDUSTRY: A CONCEPTUAL PAPER

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ABSTRACT

Late payment is a persistent issue in the Malaysian construction industry, negatively impacting subcontractors by causing financial instability, project delays, and cash flow disruptions. This research explores the factors of late payment, including poor financial management, contractor financial condition, local cultural or attitudes toward delayed payments, and the prevalent use of "pay when paid" clauses. Additionally, it examines the impacts of late payments, such as cash flow problem, increased project costs, and potential bankruptcies. The study aims to identify effective strategies to mitigate late payment issues faced by subcontractors. The key objectives are: (i) to analyze the factors contributing to late payments, (ii) to identify the impacts of late payments on subcontractors, and (iii) to determine potential solutions to improve payment practices. A quantitative research approach is employed through a structured questionnaire survey distributed to subcontractors and main contractors across Malaysia. The data collected is analysed to determine the most critical factors and effective mitigation strategies.

Keywords: late payment, construction industry, strategies

IV. INTRODUCTION

Payment in the construction sector refers to the money given to contractors, consultants, and suppliers once their services or materials have been completed and approved. Payments are crucial for these parties, causing them constant frustration as construction issues often stem from inadequate payment practices (Noor Zarina, 2006).

According to Siti Suhana (2020), advance payment, progress payment, payment upon completion and final payment are stages of payment in the construction industry. Advance payments are advances of money by the client of any project to a contractor to assist them in terms of finance for them to start up the project (Abdul Aziz et al 2009). Progress payment is early stage of payment made by client to contractor based on the work completed on site by contractor, and quantity surveyor will be assessed and evaluated the progress of the work completed and architect will then issue the interim certificate to contractor and client. Final payment represents the last stage of payment, and it is the final certificate that is issued by the architect or superintending officer (S.O) if it is PWD 203A Form of contracts. This payment is released after the contractor has fulfilled all contractual obligations, including the rectification of any defects (Roziha et al 2020).

Late payment can be defined as the employer's failure to pay within the contract period, poses a significant challenge in the construction industry (Hazizi et al., 2020). However, late payments remain a widespread problem,

affecting contractors, subcontractors, and suppliers. For years, late payment has been a prevalent and unresolved issue in the construction industry. The effects of late payment have cause contractor's cash flow issue, project delays or bring damage to the project (Siti Suhana 2020; Azman et al., 201; Ramachandra & Rotimi, 2011).

In recent years, despite many research has been carried out, there are still cases of delayed payment and non-payment happened in Malaysia construction industry. According to The Edge Malaysia on 04 Dec 2023 by Kamarul Azhar, it highlighted that Malaysian subcontractor in the construction industry face multiple challenges exacerbating late payment issues. Besides, cash flow problems which elevated material costs and delayed payments from project awarders strain subcontractors' cash flow, leading to potential financial instability and increased loans in arrears.

Our contribution to knowledge is to understand the factors contributing to late payments and identify the impacts of late payments on subcontractors. Finally, with the factors contributing to late payment and impacts of late payments on subcontractor, we aim to determine potential strategies to improve payment practices.

V. PRINCIPLE METHOD OF SUBCONTRACTOR

A. Payment upon certification

Under this payment regime, the subcontractor's right to payment is contingent upon the main contractor receiving the interim payment certificate (H. Singh, 2006). Meaning that, subcontractor will receive payment after main contractor receives interim payment certificate. This also marks the start of a specified "window period" for payment. Regardless of whether the main contractor has received the funds from the employer or if their repayment period exceeds the specified grace period, their obligation to pay the subcontractor begins once the relevant certificate is received. (Hazrin et al, 2020)

B. Direct payment from the employer

Under this payment regime, the client will directly pay the subcontractor, even though the subcontractor's payments are included in the Interim and/or Final Certificates issued to the main contractor. Unlike the conventional approach where payments flow through the main contractor, this method bypasses the main contractor for the subcontractor's payment (Hazrin et al, 2020). However, the main contractor still receives the relevant profit and attendance fees for the subcontractor's work (H. Singh, 2006).

C. Contingent payment or conditional payment

Contingent payment is a third common method for paying subcontractors, which includes various terms such as "pay if paid" clauses, "pay when paid" clauses, and "back-to-back" clauses. These clauses tie the subcontractor's payment to specific conditions, often depending on the main contractor receiving payment from the employer (Hazrin et al, 2020). This type of payment is widely used in subcontractor work.

VI. FACTORS CONTRIBUTING TO LATE PAYMENT

Various studies have been identified as a key factor in contributing to late payment in Malaysia's construction sector. From the literature review by various authors, the following seven primary factors have been highlighted:

I. Paymaster's Poor Financial Management

Qualified contractors are often hesitant to bid on projects for employers with unclear financial capacity or creditworthiness. Therefore, it is crucial for employers to maintain sound financial management, as this plays a significant role in ensuring the success of a project. Poor financial management by paymasters may lead to insufficient operating funds for contractors, particularly when they are required to make payments to subcontractors. This situation can result in delayed payments or even non-payment (Hazrin et al, 2020).

Cash flow issues often stem from deficiencies in the client's management capabilities. For instance, ineffective allocation of funds or insufficient capital to finance the project can create financial strain, as clients may struggle to maintain liquidity. Poor cash flow management can arise from inadequate processes, financial failures such as bankruptcy, or the winding up of the paymaster's other business activities. Moreover, overlook the ripple effect of economic downturn on cash flow and client's poor financial and business management. (Abdul-Rahman ,2011)

II. Paymaster's withholding of payment

As outlined in many standard contract forms, the employer or paymaster may withhold payments from the main contractor or subcontractor for various reasons (Hasmori, 2012). According to Hazrin et al, 2020, these reasons

include defective construction work, disputed work, failure to comply with key contractual provisions, third-party claims filed or evidence suggesting such claims may arise, and delays in paying for project resources (Rourke & Gentry, 2002). Such circumstances can lead the employer or paymaster to refuse or delay payments, ultimately resulting in late payment issues.

Hasmori et al. (2012) revealed that clients' employees sometimes wrongfully withhold payments, often with the intention of receiving some form of "gift" from contractors before releasing the funds. As a result, contractors are often forced to tolerate such practices to ensure they receive their payments. Additionally, employers or paymasters may delay payments to main contractors or subcontractors for various reasons, including major defects in construction work, disputes, failure to comply with key contractual terms, third-party claims or evidence suggesting such claims may arise, and delays in paying for project resources (Hasmori et al., 2012; Rourke & Gentry, 2002).

III. Local culture/Attitude

An attitude which is commonly accepted by industry or society in general can become a culture (Hazrin et al,2020). This culture reflects the prevailing attitudes and behaviors among stakeholders in the construction industry, including contractors, subcontractors, owners, and other project participants. As noted by Masrom et al. (2021), it is common for contractors in Malaysia to accept late payments from clients if the delay is fewer than five (5) working days, as they often show understanding and flexibility toward clients. This tolerance for delayed payments may stem from an ingrained culture within the Malaysian construction industry, where contractors are accustomed to accepting minor payment delays as a norm. This culture can refer to the attitudes and behaviors of various stakeholders, including contractors, subcontractors, owners, and others involved in construction projects.

IV. The Use of "Pay When Paid Clause" in Subcontractor

According to Azhari et al, (2015), a subcontractor is an individual or company engaged by a general contractor to carry out a specific portion of a construction project. A review of the literature highlights several issues faced by subcontractors, including delays in payments from general contractors, the subcontractor selection process, bonding requirements, construction insurance, safety concerns on-site, collaborative arrangements with various stakeholders, and productivity challenges. One notable issue is the use of the pay-when-paid clause, commonly included in contracts between main contractors and subcontractors or between housing developers and main contractors. This clause, also referred to as the "back-to-back" payment method, stipulates that the main contractor is only obligated to pay subcontractors after receiving payment from the employer. This arrangement is particularly relevant in cases involving nominated subcontractors, where the main contractor has not yet been paid by the employer. The pay-when-paid clause can lead to delayed payments or even non-payment, particularly affecting subcontractors (NZLC, 1999; Ye & Rahman, 2010).

The practice of pay-when-paid clauses, delays in certifying interim payments, and the involvement of multiple parties in the payment certification process were identified as the most significant factors contributing to payment delays. The pay-when-paid clause is commonly included in contracts between main contractors and smaller subcontractors. This clause stipulates that the main contractor is only obligated to pay subcontractors after receiving payment from the client. As a result, the risk of non-payment is shifted from the main contractor to smaller subcontractors, effectively absolving the main contractor of payment responsibility until they are paid by the client (NZLC, 1999; Ye & Rahman, 2010; Christian et al, 2017).

According to the study of Roziha et al, (2020), the factor of late payment contributed by the main contractor is tabulated. The three highest factors selected by both side main contractor and subcontractor which are "the use of pay when paid", "no formal contract agreement" and "contractor withhold the payment. Based on the highest response, the use of pay when paid is the preferred factor by main contractor to pay for the subcontractor. It is because the procedure is simpler than the culture created by the construction parties themselves

V. Contractors fail to agree on valuation work on site

It is a normal situation in the construction industry where one of the contracting parties disagrees about the valuation of work done. The disagreement may cause delay in certifying the amount of work executed on site (Mohamed Nor et al, 2014). According to Mohamad et al. (2023), disputes often arise when contractors disagree with the valuation of work performed on-site. This disagreement can lead to conflicts between clients and contractors, resulting in uncertified claims and, consequently, delayed payments. Similarly, late payments may occur when contractors complete work as specified in the Bill of Quantities (BQ) but take longer than the contractually stipulated time to substantiate their claims. This delay may be due to the increasing number of claims

related to design and construction administration services. The task of issuing payment certificates, which falls under the responsibility of design professionals, is often seen as burdensome and fraught with liability risks. While the primary purpose of payment certificates is to inform the owner or lender that the contractor is entitled to payment, they are frequently used by potential claimants as grounds for various legal actions (Mohamad et al., 2023).

VI. Communication

In most construction projects, inadequate communication can lead to poor project scheduling, planning, and execution. This lack of effective communication often results in insufficient project management, which may ultimately compromise the quality of the final output (Mohd Ashraf et al, 2023).

According to Gamage (2022), an effective communication system is crucial for ensuring the seamless flow of information, as it helps resolve misunderstandings, maintains the integrity of the message being conveyed, and ensures appropriate feedback from all parties. Effective communication and proper coordination are essential to prevent potential issues that may arise during construction projects. Given the importance of communication and coordination, many contract terms mandate early notification of claims and detailed information on cost and time implications. All parties must maintain consistent communication and information exchange throughout every phase of the project. However, relationship challenges in the construction industry often stem from a lack of trust and insufficient communication among project participants, particularly when subcontractors are excluded from the primary alliance, as noted by Mohd Fateh et al. (2023).

VII. Contractor's Financial Condition

According to the study of Mohd Ashraf et al (2023), construction projects will always be facing payment issues. According to Kshaf et al. (2022) highlights that the problem has worsened due to the global economic downturn, leading main contractors to delay payments to subcontractors. This strategy is primarily employed to protect the main contractor's cash flow from potential disruptions caused by subcontractors (Kshaf et al., 2022). Furthermore, based on Enshassi et al (2019), the main contractor may face delays in receiving payments from claims. These delays often stem from insufficient supporting documentation that deviates from the original project plan or on-site conditions, as well as contractual payment clauses that allow the main contractor to postpone payments to subcontractors. There are just a few reasons used by the main contractor to avoid paying the subcontractors.

VII. IMPACT OF LATE PAYMENT TO SUBCONTRACTOR

A. Cash Flow Problems Created

According to Munaain et al, (2007), cash flow is often considered the lifeblood of any business, and in the construction industry, late or non-payment by the paymaster can have a severe ripple effect throughout the payment chain. This chain typically starts from financial institutions to main contractors, then from main contractors to subcontractors, and so on. The significance of cash flow is further emphasized by the nature of the construction industry, which involves long project durations, substantial financial investments, and the prevalent use of credit terms for material purchases rather than immediate payment upon delivery (An Peer Ali, 2005b). Consequently, late or non-payment is expected to directly cause cash flow disruptions.

B. Financial Hardship

Late payments can lead to significant financial difficulties for contractors. For example, main contractors are still required to pay subcontractors and suppliers for completed work, even if they have not yet received payment from the client under the main contract. This situation places an undue financial burden on the contractor, as they are effectively forced to self-finance the project for their client, which is not a sustainable practice Munaain et al, (2007).

C. Stress on contractors and supplier Chain

Late and non-payments place significant stress on contractors, who often bid for projects competitively with slim profit margins, relying on timely payments to maintain cash flow. When clients delay payments, contractors face immense pressure to find alternative means to pay subcontractors and suppliers. This stress is exacerbated in cases of non-payment, creating severe financial and operational challenges for contractors Munaain et al, (2007).

The study by Hasmori et al (2012) analysed 393 questionnaires received from micro, small, medium and large contractors drawn from 11 states in Malaysia. The outcomes indicate that 53% and 32% of respondents respectively ranked the creation of financial hardship and creation of cash flow problems as the effect of late and non-payments in construction.

Furthermore, according to the study of Nasser (2013) analysed data received from 113 respondents comprising clients, contractors and consultants in Gaza Strip, Palestine. It was found that contractor-related factors contribute more to payment delays than owner and consultant-relates factors.

Moreover, the study of Christian et al, (2017), shows the mean scores of the impact of payment problems on performance of smaller construction firms. Increase in construction costs, decrease in profitability, delay in project completion, creation of cash flow problems, and creation of negative chain effect on other parties involved in the project rank as the most severe impact of payment problems in construction.

VIII. STRATEGIES MITIGATE LATE PAYMENT

Based on the literature review, we have concluded that there are several strategies that can be implemented to address the issue of late payment of subcontractors:

A. Implementation of a new payment mechanism

Mohd Ashraf et al (2023) suggested implementing a new payment mechanism to address developers or clients who unlawfully withhold payment. He emphasized that introducing stricter payment mechanisms and imposing personal sanctions on those illegally withholding funds can effectively reduce delays and non-payment issues would be a great advantage to the subcontractor.

B. All parties fulfill their contractual obligations

All parties must fulfill their contractual obligations to verify claims and ensure compliance with terms before certifying payments. Yap et al. (2017) highlighted the importance of establishing a committee to oversee claim submissions, ensuring they align with contractual requirements, product delivery, and other specified criteria before payments are approved. Contractors are also advised to exercise caution when selecting paymasters and entering contracts.

C. Amending legislation and imposing penalties for withholding payments

According to Bäckstrand & Fredriksson (2022) noted that under common law, a contract can only be terminated if one party commits a repudiatory breach. If a party refuses to fulfill their contractual obligations, it constitutes a breach, and penalties can be applied to deter such behavior. This approach can help small subcontractors resolve payment issues and reduce disputes.

D. Notification to the client

In terms of late payment by the main contractor to the subcontractor, Roziha et al. (2020) suggested that subcontractor need to notify the client of the project of the late payment. Written notifications allow contractors, especially new or smaller ones, to prepare financially and ensure smooth project execution. Early acknowledgment of payment delays helps contractors manage budgets, purchase raw materials, and maintain project timelines. Additionally, a written notices serve as evidence in case of disputes, reducing the likelihood of conflicts over payments.

E. Advance Payment Bond

Oke et al (2013) mentioned a bond is a formal contract to repay borrowed money with interest at fixed intervals, Emily (2009) asserted that Construction bonding is a risk management tool used to protect project owners and developers. Advanced Payment bond ensures that the contractors fulfils contract within the contract period. Xianhai (2002) stated that in different developed countries, either a guarantor or a bondsman, as appropriate, may be the person who agrees to assume the contractor’s obligation to the owner when the contractor fails to perform.

F. Tighter Selection Process of Main Contractor / Client

Roziha et al., (2020) suggests the contractor to take proactive measures before accepting any jobs. The subcontractor needs to evaluate the financial stability of the main contractors be to prevent potential risks. Another strategy proposed by respondents to overcome late payment issues, which was not included in the questionnaire, is that all businesses should be registered with Suruhanjaya Syarikat Malaysia (SSM), a government requirement.

Additionally, contractors should hold certification from Pusat Khidmat Kontraktor (PKK), which is essential for participating in government projects. These measures ensure that contractors are qualified and capable of handling projects effectively. The second was to include a standard contract clause regarding payments between the main contractor and domestic subcontractor. This clause should specify penalties, particularly in cases of late payments, such as blacklisting the contractor's name or imposing a levy charge. (Roziha et al, 2020).

CONCLUSION

This study has explored the critical issue of late payment faced by subcontractors in the Malaysian construction industry due to the actions of main contractors. Through an in-depth analysis, it is evident that delayed payments significantly impact subcontractors' financial stability, project progress, and overall industry sustainability. The findings highlight key factors contributing to late payments, including poor financial management by main contractors, cash flow constraints, and contractual loopholes that allow for delayed disbursement of funds.

To mitigate these challenges, several recommendations have been proposed. Strengthening contractual frameworks, enforcing stricter legal regulations, and promoting transparent payment practices can help ensure timely payments. Additionally, fostering better financial planning and adopting digital payment systems could further enhance efficiency in payment processes.

Overall, addressing late payment issues is essential for creating a more resilient and efficient construction industry in Malaysia. By implementing the suggested strategies, stakeholders can improve subcontractor confidence, enhance project delivery, and contribute to a healthier construction ecosystem. Future research could explore the effectiveness of emerging financial technologies and policy interventions in mitigating payment delays, further supporting the industry's long-term growth.

METHODOLOGY

This conceptual paper employs an extensive literature review as the primary research methodology. The literature review involved the systematic collection, evaluation, and synthesis of existing studies, journal articles, conference papers, and industry reports related to late payment issues in the Malaysian construction industry. The aim was to identify common factors contributing to late payment, its impacts on subcontractors, and effective mitigation strategies. By analyzing a wide range of scholarly sources and industry findings, this approach ensures a comprehensive understanding of the subject and provides a solid foundation for proposing strategic recommendations.

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A CRITICAL REVIEW OF STRATEGIES FOR ADVANCING GREEN BUILDING DESIGN AND IMPLEMENTATION IN COMMERCIAL SECTORS

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ABSTRACT

Green commercial buildings are environmentally responsible and resource-efficient structures. Green building is the fundamental element of sustainable development as it defines style of buildings designed and constructed in accordance with environmentally friendly principles. In this regard, this study draws attention to evaluating and addressing the most important topics: the priority criteria for the advancement of green buildings for commercial buildings. Therefore, to enhance and promote the development of green buildings, it is crucial to comprehend the factors that determine the successful application of green features to ensure that the obstacles during the construction process have been overcome. Through comprehensive literature reviews, surveys, and case studies, the research identifies key criteria such as energy efficiency, material selection, water conservation, and indoor environmental quality. By analyzing stakeholder perspectives, including architects, builders, and tenants, this research highlights the most impact criteria for promoting green building initiatives. The findings offer valuable insights for policymakers, developers, and industry professionals, ultimately contributing to a more sustainable built environment. This study highlights the elements driving the acceptance of green buildings and barriers to their execution, providing valuable insights for stakeholders engaged in the ongoing discourse concerning green building development. Consequently, interested parties will gain better understanding of the factors affecting the priority criteria for the progression of green buildings in the commercial buildings.

Keywords: Sustainable Buildings (SB), advancement, Green Buildings (GB), construction, priority criteria, environmentally friendly

I. INTRODUCTION

According to Bungau et al., 2022, the concept of green buildings encompasses a wide array of practices, technologies, and materials aimed at improving energy efficiency, reducing waste, and creating healthier living environments. However, despite the potential benefits associated with green construction, its widespread adoption has been hampered by several persistent challenges. Key among these challenges are the complexities surrounding the definition and measurement of what constitutes a "green" building. (Esa, M. R., et al., 2011). Current certifications, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), while beneficial, can often create confusion and inconsistencies in application. Those systems are designed to prioritize and address the sustainability pillars. Consequently, the lack of universally accepted criteria can deter builders and stakeholders from investing in green technologies, thereby slowing down the momentum needed for transformation in the industry. (Awadh et al., 2017)

Moreover, the financial implications of adopting green building practices cannot be overlooked. Initial costs for sustainable materials and technologies often present a significant barrier to entry for many developers. Despite the long-term savings and environmental benefits, the short-term economic challenges can lead to hesitation

among stakeholders. Additionally, insufficient knowledge and understanding of green technologies can result in poor implementation and missed opportunities for optimizing sustainability. Therefore, addressing these issues is imperative for fostering an environment conducive to the advancement of green buildings. (Horr, et al., 2016). According to a survey conducted in Malaysia, one of the biggest obstacles to the growth of green buildings in that nation is a lack of public awareness, as observed by Jaffar, et al., (2022) in their study. To develop a local construction industry that can be more user- and environmentally- friendly especially in Malaysia, one challenge that needs to be addressed is a lack of awareness and understanding.

II. LITERATURE REVIEW

Introduction of Green Buildings

According to United States Environmental Protection Agency (2012), a green building refers to the practice of designing, building, and operating structures in an environmentally responsible and resource-efficient way, throughout their entire lifespan. This includes the stages of site selection, design, construction, operation, maintenance, renovation, and deconstruction. Green building practices enhance and extend traditional design considerations such as economy, functionality, durability, and occupant comfort.

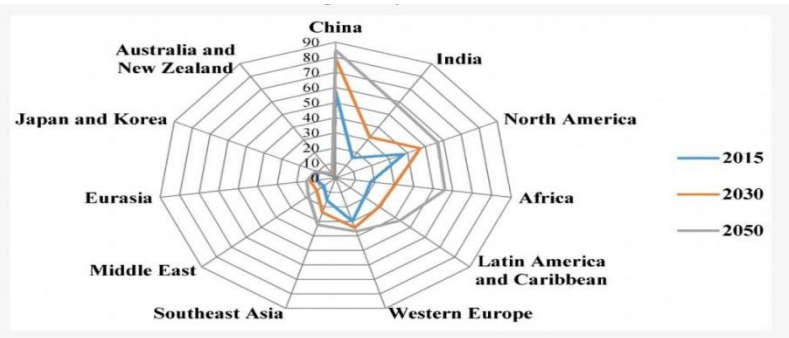


Figure 1. Buildings Floor Area Growth by Region in Billion m^2

Source: Towards Low-GHG and Resilient Buildings 2016

According to the study of Khan, et al., 2019, Figure 1 shows the projected growth of sustainable living. It can be seen that it categorized into viable, bearable, and equitable dimensions, spanning three years: 2015, 2030, and 2050, measured in billions of square meters. This significant expansion in building floor area necessitates a well- organized plan and strategic resource management by utilizing various tools and techniques to facilitate the adoption of green buildings. As a result, green buildings contribute to achieving nine distinct Sustainable Development Goals (SDGs). In view of the rapid growth of building floor area in many nations, researchers have developed a variety of techniques or strategies to accomplish the sustainability goals across different aspects of life.

Priority Criteria for the Advancement of Green Buildings

The definition of sustainable building principles aims to reduce the impact over the course of a building's life cycle. To achieve sustainable buildings to help with issues of environmental impact, the International Council of Research and Innovation in Building and Construction (CIB) working commissions came up with several proposals. Creating green buildings is one of them. According to the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), a green building design is one that achieves excellent performances over its whole life cycle. There are certain criteria listed to be rated to identify if the buildings meet criteria needs. (Retno Rahardjati et al. 2010). Green Building Rating System (GBRS) was created to assign rating points for buildings that reach certain requirements and show whether their designs are environmentally friendly. (Alalouch, et al., 2016).

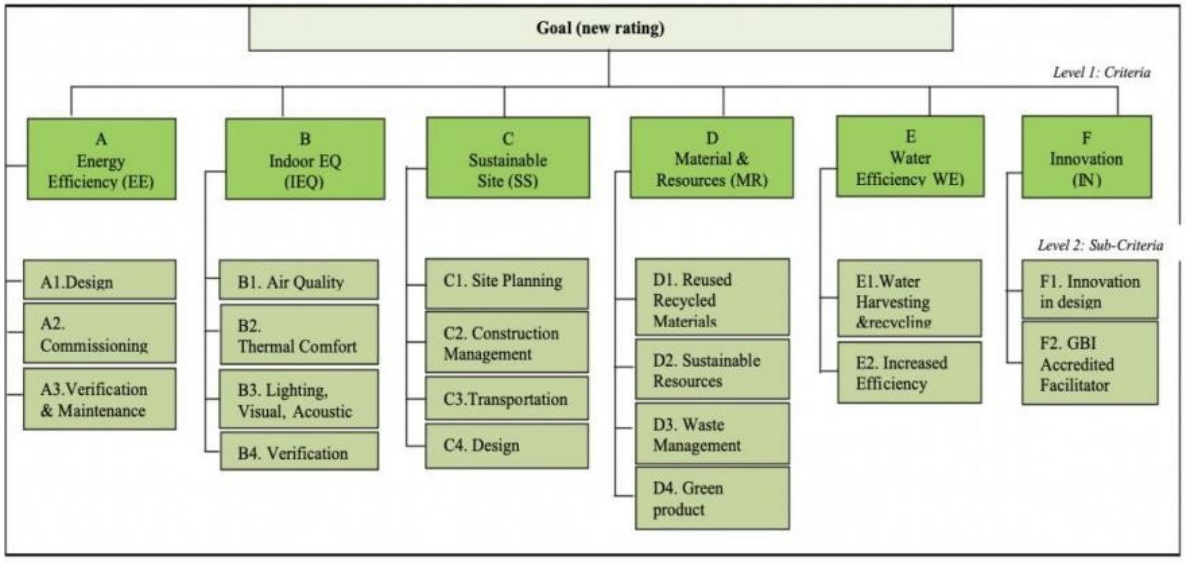


Figure 2. Criteria and Sub-criteria of GBIM

Source: Retno Rahardjati et al., 2010

Figure 2 indicates the criteria and sub-criteria of the Green Buildings Index Malaysia (GBIM). According to the study of Retno Rahardjati et al. (2010), it stated six criteria in the current GBIM. There are Energy Efficiency (EE), Indoor Environmental Quality (IEQ), Sustainable Site (SS), Material & Resources (MR), Water Efficiency (WE), and Innovations (IN). Energy Efficiency has the biggest distribution among the six criteria. Two levels and a target have been set up through the analysis process. The six primary GBIM criteria are categorised as level 1, and each criterion has a level 2 sub-criterion.

Indoor Environmental Quality (IEQ)

Since people nowadays spend most of their time in an interior environment, indoor environmental quality (IEQ) is one of the key variables influencing occupants' physical and mental well-being. (Horr, et al., 2016). In recent years, green buildings have gained popularity as a way of lowering energy consumption and enhancing human health and IEQ. (Karimi et al., 2023). Research indicates that certain interior environmental discomfort symptoms such as the rate of Indoor Air Quality (IAQ) might significantly affect occupants' ability to perform their best at work. (Apte et al., 2000). To improve indoor air quality (IAQ) in a building, two main design strategies are typically used. The first involves increasing ventilation rates to reduce air pollutants. The second focuses on minimizing pollution sources both inside and outside the building to prevent contaminants from entering the indoor environment. (Daisey, et al., 2003). Indoor environmental quality, according to the Centers for Disease Control and Prevention, is the state of a building or place that has an impact on the health and well-being of its occupants. Improved occupant well-being is linked to the advantages of enhancing indoor environmental quality through sustainable design techniques.

Challenges in Adopting the Green Buildings Practices

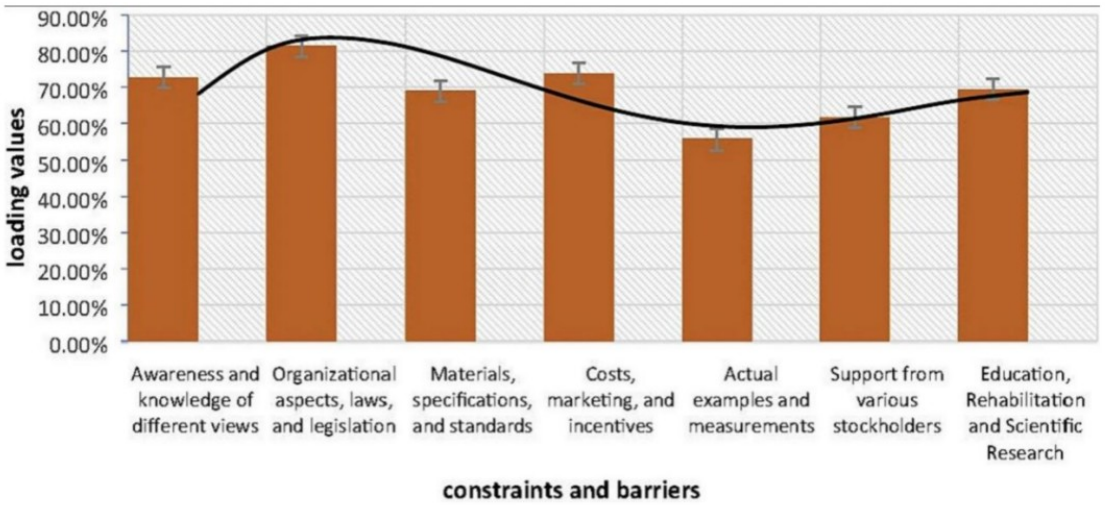


Figure 3. Constraints and Barriers of Implementing Sustainability Buildings Practices in Jordan
Source: Jaradat, H et al., 2023

Figure 3 highlights the key constraints and barriers to implementing sustainable building practices in Jordan. These include factors such as awareness and understanding of different perspectives, organizational issues, material availability, costs, practical examples and measurements, support from stakeholders, as well as education, training, and scientific research. Previous studies have identified institutional and organizational challenges as primary reasons for the slow adoption of sustainable construction practices. Additionally, the lack of national standards for sustainable materials and green building codes has further delayed progress. One of the study's key findings was the widespread lack of understanding of how to effectively implement sustainable building practices. (Jaradat, H et al., 2023).

Lack of Awareness Level and Knowledge

The findings of a study on the prospects for advancing sustainable construction (SC) methods in Kuwait are presented in the paper of AL Sanad, S. 2015. It shows that by evaluating the state of the sustainable construction practice, the level of knowledge and awareness among the construction stakeholders are the main forces behind the adoption of green practices and become the serious obstacles to sustainable construction. Additionally, the lack of awareness about the long-term environmental, economic, and social benefits of sustainable construction further exacerbates the situation. Therefore, the absence of clear guidelines, incentives, and regulatory frameworks could facilitate the transition towards more sustainable practices.

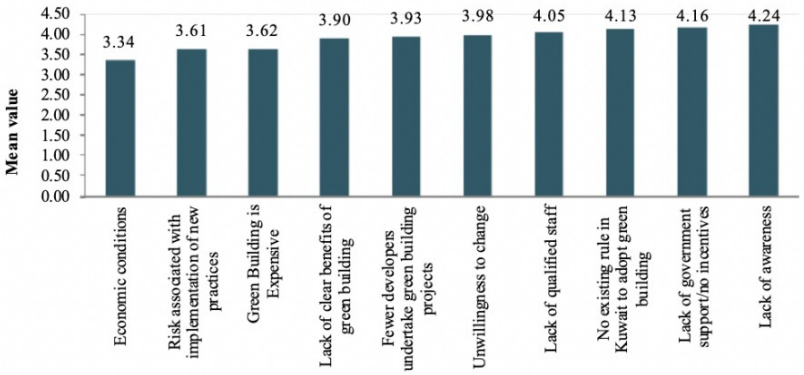


Figure 4. Perception of the Barriers towards Implementation of Green Construction Practices
Source: AlSanad, 2015

Figure 4 presents the respondents' perceptions regarding the key barriers to the adoption of green building practices, ranked according to their mean values. The findings indicate that the most significant challenge

identified is the "lack of awareness" (mean = 4.24), followed closely by the "lack of government support/no incentives" (mean = 4.16). These results suggest that both insufficient education on sustainable building practices and the absence of adequate policy support are critical obstacles in advancing green buildings.This aligns with previous studies by Winston, which emphasize the importance of regulatory frameworks in promoting sustainable development. Conversely, the least significant barriers, according to respondents, are the "risks associated with the implementation of new practices" (mean = 3.61) and "economic conditions" (mean = 3.34). Given that green construction is still a relatively new concept in many regions, raising awareness among stakeholders about its benefits is crucial to its widespread adoption. Effective educational initiatives can help to overcome those key challenges, particularly the lack of knowledge about sustainable building techniques and their long-term advantages. Economic concerns remain a major deterrent, with respondents perceiving "green buildings as expensive" and citing overall "economic conditions" as fundamental obstacles. The financial implications of sustainable construction are particularly impact in profit-driven industries where project contracts are often awarded based on the lowest bid.

III. METHODOLOGY

Research process

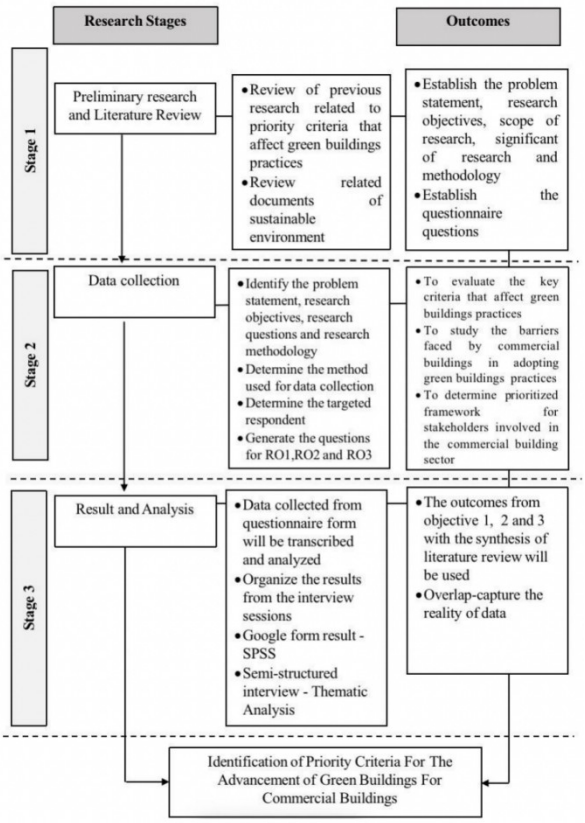


Figure 5. Research Process for Identification of Priority Criteria for The Advancement of Green Buildings for Commercial Buildings

Figure 5 indicates that three stages will be utilized during the research process. Stage 1 represents the preliminary research and literature review, Stage 2 represents the part of data collection, and Stage 3 represents the result and analysis.

I: In this initial stage, the researcher will conduct a comprehensive and detailed review of previous research that is related to the key criteria influencing green building practices to have a better understanding of this research's objectives. After that, the researcher will establish the problem statement and research objectives (RO1, RO2, RO3), determine the scope of research, and select the appropriate methodology. Additionally, the researcher will develop a set of the questionnaire questions to achieve RO1 in stage 1.

II: Within the data collection stage, the researcher will determine the appropriate methods for data collection. This involves selecting a group of respondents who are relevant to the study. The research questions that address RO1, RO2, and RO3 will then be distributed to these respondents to collect professional opinions and data, ensuring alignment with the research objectives of this study.

III: During the final stage, the data collected from the questionnaire form will be transcribed and analyzed by using specific data analysis tools. The researcher will be organizing and synthesizing the results from the interview session conducted. The findings related to RO1, RO2, and RO3 will be integrated with insights from the literature review to ensure a comprehensive analysis.

Data Collection Method

a. Questionnaire Development

Questionnaires in the form of an online survey are conducted to gather primary data of RO1. Closed-ended questions will be used for all the questions on the list. The questionnaire for this study was designed based on the literature evaluation of the existing research paper. The questionnaire for this research comprises two sections, each designed to achieve the research objectives. Section A of the online survey gathers demographic information from the respondents, including details such as name, gender, race, and years of work experience. On the other hand, section B consists of 4 questions that present a few criteria related to the green building projects. Respondents have to rank the criteria based on their past experiences regarding the green building's practices. To facilitate this, a Likert scale ranging from 1 to 5 is employed; scale 1-strongly disagree, scale 2-disagree, scale 3-neutral, scale 4-agree, and scale 5-strongly agree. In addition, if they felt it was essential, the respondents were free to add additional criteria to the list. For this research, one commonly used method is probability sampling, where every individual in the population has a known and equal chance of being selected. Within probability sampling, purposive sampling can be used, where researchers intentionally select participants who possess specific characteristics or knowledge relevant to the study, ensuring that the sample is highly focused on the research objectives.

b. Interview Session Development

To achieve RO2 and RO3, interview research methodology will be conducted with key stakeholders in the commercial construction industry, including architects, engineers, property developers, and facility managers. To enhance the validity of the data, various strategies were employed, including gathering multiple sources of evidence and having key informants review the relevant cases. These stakeholders provided valuable insights into their experiences and perspectives regarding the barriers and challenges dealt with in adopting green building practices. The feedback collected was analyzed.

Expected Results

The purpose of the RO1 is to yield a comprehensive understanding of the key criteria that significantly influence the adoption and success of green building practices in commercial buildings. By analyzing stakeholder insights and literature data, the research aims to prioritize these criteria, highlighting the most impact and feasible elements that should be emphasized during planning and development stages. These criteria may include aspects such as energy efficiency, sustainable materials, indoor environmental quality, and water conservation, among others. The goal is to provide a clearer pathway for stakeholders to make informed decisions that align with environmental and economic sustainability.

Another anticipated outcome of the RO2 is the identification of core barriers and challenges that hinder the advancement of green building practices. Commercial buildings, particularly in developing urban environments, often face obstacles such as high initial costs, limited awareness, and regulatory constraints. This paper will not only enumerate these challenges but also examine their root causes and prevalence across different sectors. By gaining a better understanding of these barriers, the paper can propose targeted solutions to overcome them, helping to create a more supportive ecosystem for green initiatives.

From the aspect of RO3, it is expected to culminate in the development of a prioritization framework tailored for stakeholders in the commercial building industry. This framework will serve as a practical guide for developers, policymakers, and investors, aiding them in strategically focusing on the most essential criteria while planning, constructing, or upgrading commercial buildings. Ultimately, this output aims to bridge the gap between green building ideals and practical implementation, encouraging a more widespread and effective adoption of environmentally responsible construction practices.

Table 1. Table of Variables

No.	Author (s)	Year	Title	Aim/ Objectives	Method(s)	Data Analysis	Findings
1.	Serkan Eti, Hasan Dincer	2023	Determination of priority criteria in green building transformation: An analysis on the service industry	Identify priority criteria in green (net zero energy) building transformation.	- Literature evaluation(to find out 10 indicators) - TOP-DEMATEL methodology.	T-Spherical fuzzy sets	**Ranking** 1. Effective waste management 2. Innovative production and design 3. Occupational safety 4. Sound insulation 5. Renewable energy sources
2.	Visar Hoxha, Hasan Dinçer, Serhat Yuksel	2023	Analysis of strategic priorities of green building projects for the efficient energy consumption	Investigate the contributing factors that contribute to the effectiveness of sustainable green buildings in Malaysia concerning the green building index (GBI) tool.	- Questionnaire	- TOPSIS - DEMATEL	**Ranking** 1. Government supervision 2. Incremental cost 3. Property management 4. Energy Efficiency 5. Water Efficiency 6. Innovation 7. Awareness of environmental protection 8. Indoor Environmental Quality 9. Sustainable Site Planning and Management 10. Materials and Resources
3.	Hedieh Chorom et al.	2020	Prioritization of the Green Building's Criteria	To identify and prioritize green building's criteria in the Iranian metropolises	Interview Session	Super Decisions software	**Ranking** 1. Education and culture 2. Energy consumption management 3. Water consumption management 4. Waste management, 5. Sewage management 6. Materials, 7. Quality of indoor space, 8. Environmental quality
4.	Tayyab Ahmad	2023	Performance Criteria Priorities in Green Buildings: A Proof-of-Concept Study	To understand the priorities given to different performance criteria and the factors resulting in such priorities	Online Survey	SPSS	**Ranking** 1. Cost 2. Quality 3. Environmental Sustainability 4. Schedule 5. Safety 6. Economic Sustainability 7. Social Sustainability

Table 1 shows that the variables that obtained from the previous research papers. It outlines the foundational elements needed to assess and prioritize the advancement of green building practices. It categorizes the research variables into dependent and independent groups to streamline the analytical process. The independent variables include a set of green building criteria such as energy efficiency, water usage, indoor air quality, material sustainability, and innovation in design. These variables represent the core elements believed to influence the success and effectiveness of green building implementation. Each variable will be evaluated through stakeholder feedback and existing literature to determine its perceived importance and impact.

Meanwhile, the dependent variable in this study is the level of advancement in green building practices within commercial buildings. This outcome is measured based on the extent to which the independent variables are integrated and rationalized in actual building projects. By establishing a clear relationship between these variables, the paper aims to reveal which green building criteria are most strongly associated with successful implementation. This structure allows for a logical and evidence-based prioritization process, ensuring that the results are both meaningful and applicable in real-world commercial development contexts.

ACKNOWLEDGMENT

The authors would like to express my deepest appreciation to Assoc. Prof. Sr. Ts. Dr. Md Azree Othuman Mydin for his continuous support and thank the Ministry of Higher Education for providing financial support to this research work through the Fundamental Research Grant Scheme (FRGS/1/2022/TK01/USM/02/3).

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ANALYSIS THE WORKABILITY OF RAINWATER HARVESTING DRAINAGE SYSTEM IN REDUCING THE RISK OF FLASH FLOODS IN GEORGETOWN

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ABSTRACT

This research investigates the role of rainwater harvesting drainage systems in mitigating the risk of flash floods in Georgetown, a city increasingly susceptible to flooding due to urbanization and climate change. As urban areas like Georgetown continue to expand, challenges related to impervious surfaces—such as roads, buildings, and pavements to become more pronounced, as these surfaces hinder natural water infiltration and exacerbate surface runoff during heavy rainfall events. This study evaluates the effectiveness of Georgetown's existing rainwater harvesting drainage infrastructure, focusing on system design, implementation, and operational efficiency in managing stormwater flow. A mixed-methods research design will be employed, integrating both qualitative and quantitative methodologies. Qualitative approaches, including case studies and expert interviews, will explore innovative drainage designs and examine the practical challenges associated with system implementation. Quantitative techniques, such as structural analysis, will provide empirical data on system performance under various rainfall scenarios. Stakeholder perspectives, gathered through interviews with urban planners and engineers, along with real-world case studies, will provide valuable insights into the operational aspects and challenges of system integration. The study hypothesizes that rainwater harvesting drainage systems are integral in reducing flash flood risks by effectively capturing, storing, and managing excess rainfall within designated catchment areas. By enhancing groundwater infiltration and reducing surface runoff, these systems contribute significantly to flood risk mitigation while promoting sustainable urban water management practices. Ultimately, this research underscores the importance of innovative drainage solutions in addressing urban flooding challenges, with the goal of providing a strategic framework for improving flood resilience and advancing drainage infrastructure in Georgetown and similar urban environments.

Keywords: *Rainwater Harvesting, Drainage System, Risk of Flash Flood*

I. INTRODUCTION

This research aims to analyze and optimize drainage designs by evaluating the integration of advanced rainwater management systems to mitigate the risk of flash floods. It seeks to understand the challenges posed by current systems and propose design improvements that enhance the efficiency and effectiveness of rainwater management systems in urban buildings, ensuring optimal performance during heavy rainfall events. Urban areas, particularly those undergoing rapid urbanization and facing the exacerbating effects of climate change, are increasingly vulnerable to flash floods. This vulnerability is often compounded by the widespread use of impervious surfaces such as roads, rooftops, and pavements, which prevent natural water infiltration and lead to increased stormwater runoff. This, in turn, puts immense pressure on urban drainage systems, which are already struggling to cope with the growing volume of runoff. The consequences are far-reaching, impacting environmental sustainability, economic stability, and social welfare, including infrastructure damage and displacement of populations (Ali Zaiter, Nuridah, et al., 2024).

Urban drainage systems play a pivotal role in managing stormwater runoff by channeling excess surface water during rainfall events and reducing flood risks to manageable levels. These systems typically consist of two components: the primary system, including roads and gutters, which handles surface water, and the secondary or minor system, which comprises subsurface drains that direct stormwater to rivers, reservoirs, or treatment facilities. Flash floods, characterized by their rapid onset and devastating impact, pose significant risks to urban areas. These events, often occurring with little warning, result in widespread destruction of infrastructure, homes, crops, and, tragically, human lives (Omar M. Abdeldayem, Mohamed K. Mustafa, 2020).

This study specifically investigates the effectiveness of rainwater harvesting drainage systems in reducing flash flood risks in Georgetown, an urban area frequently affected by heavy rainfall and subsequent flooding. As the city continues to experience rapid development and climate-induced rainfall variability, the current drainage infrastructure is increasingly challenged to manage stormwater efficiently. By conducting a detailed case study, the research aims to assess the capacity of the existing drainage system to handle peak rainfall events, identify design deficiencies contributing to flooding, and explore opportunities for integrating rainwater harvesting strategies with public water management frameworks. Through this analysis, the study seeks to propose innovative drainage designs that enhance flood resilience, promote sustainable water use, and strengthen Georgetown's overall urban water management strategy.

Additionally, this research focuses on improving urban building designs by incorporating effective rainwater management systems to address the growing problem of flash flooding and promote sustainability. Many urban drainage systems, particularly those in older or rapidly developing cities, are outdated or inadequate to handle contemporary challenges such as increasing impervious surfaces and the accelerating effects of climate change. This research will identify critical deficiencies in existing systems that contribute to flash floods and propose solutions, including systems designed to capture, filter, and reuse rainwater for non-potable uses. These systems can reduce dependence on municipal water supplies, lower operating costs for buildings, and mitigate the environmental impacts of urbanization. By optimizing rainwater management in urban buildings, this study aims to enhance flood resilience, promote water conservation, and provide a robust framework to guide sustainable urban development practices and decision-making.

Based on the research conducted by the researcher in Georgetown, Penang, there are three main objectives that aim to address the challenges of water management in the area.

1) To Study the types of rainwater harvesting drainage systems in Georgetown.
2) To measure the workability of the current drainage system and its effectiveness in managing water flow during heavy rains.
3) To Suggest the best design of rainwater drainage system to enhance water management in reducing flash floods.

II. LITERATURE REVIEW

Rainwater Harvesting and Drainage Systems

Rainwater harvesting is one of the promising ways of supplementing the surface and underground scarce water resources in areas where existing water supply system is inadequate to meet demand. Rainwater harvesting is one of the measures for reducing impact of climate change on water supplies. (Abeokuta, 2010) Rainwater harvesting is a promising method of collecting and storing rainwater to supplement surface and underground water resources, especially in areas where the existing water supply is not enough to meet demand. It is also considered an effective measure to reduce the impacts of climate change on water availability (Abeokuta, 2010). In Bangladesh, rainwater harvesting is commonly practiced in coastal and arsenic-affected rural areas, but urban communities remain hesitant to adopt this system due to doubts about potential water savings and the time it takes to recover the initial investment cost. To address severe water shortages, the government of Bangladesh now requires all proposed new buildings in major cities to include rainwater harvesting systems. Similarly, Jordan faces significant water scarcity, with current water usage exceeding renewable supply. Although rainwater harvesting from rural and urban catchments has not been widely implemented in Jordan, collecting rainwater from rooftops, roads, and parking lots is seen as a practical solution to increase water availability for domestic use and help combat chronic water shortages (Abdulla Fayez, Al-Shareef A.W, 2009).

Urban drainage systems play a crucial role in managing storm water runoff in urban areas. They are designed to transport the excess surface water during the events of rain from urban areas and reduce floods to acceptable levels of service. In recent years, the occurrence of urban flooding has been more frequent due to climate changes and rapid urbanization which resulted in intense rainfall events with longer durations and significant increases in the impervious layers especially in large cities. Urban drainage systems are essential for managing stormwater in cities, helping reduce flood risks by channelling rainwater away. They consist of two parts: a major system (roads

and gutters) that carries surface water, and a minor system (subsurface drains) that directs the water to areas like rivers or treatment plants. These systems are linked through inlets like manholes. Designing urban drainage systems (UDS) for extreme weather and uncertain future conditions is tough because many factors, like social policies, city characteristics, and water flow, must be considered. To tackle these challenges, scenario planning is commonly used to explore different possible futures and manage uncertainty in the design process. However, few studies have focused on creating long-term solutions for UDS that can address multiple levels of risk at the same time, considering both current and future scenarios (Soon Ho Kwon, Dong hwi Jung, 2023). Urban areas, such as Georgetown, face higher risks of flash floods due to increased impermeable surfaces like roads and buildings, which prevent rainwater from being absorbed into the ground. Rainwater drainage systems can significantly reduce runoff, which is a primary contributor to flash floods. Furthermore, the integration of rainwater drainage systems into urban planning is key to developing resilient flood management strategies.

The integration of rainwater harvesting and urban drainage systems can provide significant benefits for managing water resources in urban environments, offering a more sustainable approach to addressing both water scarcity and flood risks. Rainwater harvesting involves collecting and storing rainwater for various purposes, including domestic use, irrigation, and industrial needs, which can help reduce reliance on conventional water supply systems. Urban drainage systems, on the other hand, are designed to handle stormwater runoff by channeling excess water away from urban areas to prevent flooding. Although the primary goals of these systems differ, they are interconnected in that they both contribute to improving water management and resilience in cities. By capturing rainwater through harvesting systems, cities can reduce the volume of water that enters drainage systems, thus alleviating pressure on these infrastructures during heavy rainfall events. In turn, this can help minimize flood risks and enhance overall water management strategies (Abdulla Fayez, Al-Shareef A.W., 2009; Ali Zaiter, Nuridah et al, 2024).

Moreover, urban drainage systems can be designed with rainwater harvesting in mind, offering opportunities to enhance both systems' efficiency. For example, in cities where stormwater drainage infrastructure is outdated or struggling to keep up with rapid urbanization, integrating rainwater harvesting systems can provide much-needed relief by reducing the volume of stormwater entering drainage networks. This could be especially beneficial in regions where urban areas face frequent flooding due to heavy rainfall or poor drainage infrastructure. The combination of rainwater harvesting and efficient drainage systems helps reduce the overall strain on municipal resources, addresses urban water management challenges, and contributes to the development of more sustainable and climate-resilient cities. This integrated strategy, when implemented properly, can have long-term benefits in terms of water conservation, flood risk management, and urban sustainability (Ali Zaiter, Nuridah et al., 2024; Soon Ho Kwon, Dong Hwi Jung, 2023).

Regulations And Guidelines for Research

Uniform Building By-Laws (UBBL) 1984

The Uniform Building By-Laws (UBBL) 1984 is a piece of legislation in Malaysia that regulates building design and construction. Uniform Building By-Laws (UBBL) 1984 plays a crucial role in promoting sustainable urban development in Malaysia by integrating water management solutions into building regulations. The By-Laws mandate the installation of rainwater harvesting systems, such as storage tanks and filtration units, to reduce reliance on municipal water supplies for non-potable uses like irrigation and flushing toilets. Additionally, the UBBL emphasizes water-saving fixtures like low-flow faucets and dual-flush toilets, along with drainage systems that minimize stormwater runoff through permeable surfaces and detention ponds. These provisions address the challenges of rapid urbanization and climate change, ensuring urban development aligns with sustainability goals by creating more self-sufficient buildings and resilient water management systems. Through these regulations, the UBBL fosters a more sustainable approach to urban planning and water conservation. Within the UBBL 1984, the following regulations are particularly relevant to rainwater management and stormwater control:

1) Regulation 36 - This regulation mandates the installation of rainwater harvesting systems in buildings for non-potable water usage, such as for irrigation and toilet flushing. This requirement is designed to reduce dependence on municipal water supply systems.
2) Regulation 49 - Pertains to drainage design and the proper management of stormwater runoff. It sets out the minimum standards for building drainage systems, ensuring they are capable of handling rainfall without contributing to flooding or waterlogging. This includes requirements for stormwater collection and safe discharge systems.
3) Regulation 110 - Addresses the provision of permeable surfaces and detention ponds, which are designed to reduce stormwater runoff and facilitate water absorption into the ground. These provisions are aimed at mitigating urban flooding and supporting sustainable water management practices.

These regulations, embedded within the UBBL 1984, are crucial in ensuring that building designs incorporate sustainable water management systems, addressing urbanization challenges and contributing to overall flood resilience and water conservation in Malaysia.

The Street, Drainage, and Building Act 1974 (Act 133)

The Street, Drainage, and Building Act 1974 (Act 133) is a crucial regulation in Malaysia for managing urban development and flood risks. Part III of this Act focuses on the design, construction, and maintenance of drainage systems, requiring public and private developments to implement effective drains, culverts, and retention ponds to prevent flooding. These systems must handle both regular and extreme rainfall while being maintained and upgraded by developers and local authorities to address urbanization and climate change. While primarily aimed at flood prevention, the Act also supports rainwater harvesting by enabling excess runoff to be stored for non-potable uses like irrigation and cleaning, reducing reliance on municipal water supplies. By linking drainage infrastructure and rainwater harvesting, Act 133 promotes sustainable urban water management, helping cities manage stormwater effectively while minimizing their environmental impact. The following regulations within Act 133 are relevant to rainwater harvesting and sustainable drainage management:

1) Section 18 - This section requires the construction of adequate drainage systems in urban and rural developments to ensure that water is effectively managed and that the risk of flooding is minimized. This includes both surface and subsurface drainage systems. It sets guidelines for the design of drainage systems that can handle excessive rainfall and stormwater runoff.
2) Section 19 - Addresses the requirement for retention ponds, detention basins, and culverts, which help manage stormwater runoff and mitigate the risk of flooding. These facilities are designed to store and slowly release stormwater, reducing the pressure on urban drainage systems during extreme weather events.
3) Section 24 - Allows for the installation of rainwater harvesting systems as part of the broader drainage and water management framework. This section supports the integration of rainwater storage solutions that can capture excess runoff and store it for non-potable uses, such as irrigation, cleaning, and flushing toilets. This helps reduce the demand on municipal water supplies and promotes sustainable water management practices.
4) Section 25 - Stipulates that developers are required to maintain and upgrade the drainage systems regularly to ensure their continued effectiveness, especially in the face of rapid urbanization and climate change. It emphasizes the importance of maintaining infrastructure to handle increased stormwater runoff due to urban development.
5) Regulation 8 - In the Drainage and Building Regulations under the Act, this regulation deals with stormwater management, ensuring that drainage systems are designed to accommodate extreme weather events, providing clear guidelines for the handling of both regular and intense rainfall. This regulation ensures that all drainage infrastructure, including retention systems, is appropriately designed, built, and maintained to manage the additional runoff from impervious urban surfaces.

Together, these provisions of Act 133 establish a comprehensive framework that addresses flood prevention and supports sustainable urban water management. By linking drainage systems with rainwater harvesting, the Act promotes an integrated approach to managing stormwater, reducing flooding, conserving water resources, and enhancing the resilience of urban areas to climate change and urbanization pressures.

III. SCOPE OF RESEARCH

The Scope of this research will focus on urban areas with significant rainfall and flash flood risks, such as coastal cities or regions experiencing monsoon seasons. This study was conducted in Georgetown, Penang. Georgetown, the capital city of Penang, Malaysia, is famous for its unique cultural heritage and old colonial buildings. However, being a low-lying coastal city, it often faces issues with flooding, especially during heavy rains. The city is choosed has grown drastically over the years, with more buildings and reclaimed land, which puts extra pressure on its drainage systems. These old drainage systems struggle to handle the large amount of rainwater, causing flash floods in many areas. This has made it important for Georgetown to find better ways to manage rainwater and reduce flooding to keep the city safe and sustainable. Penang.

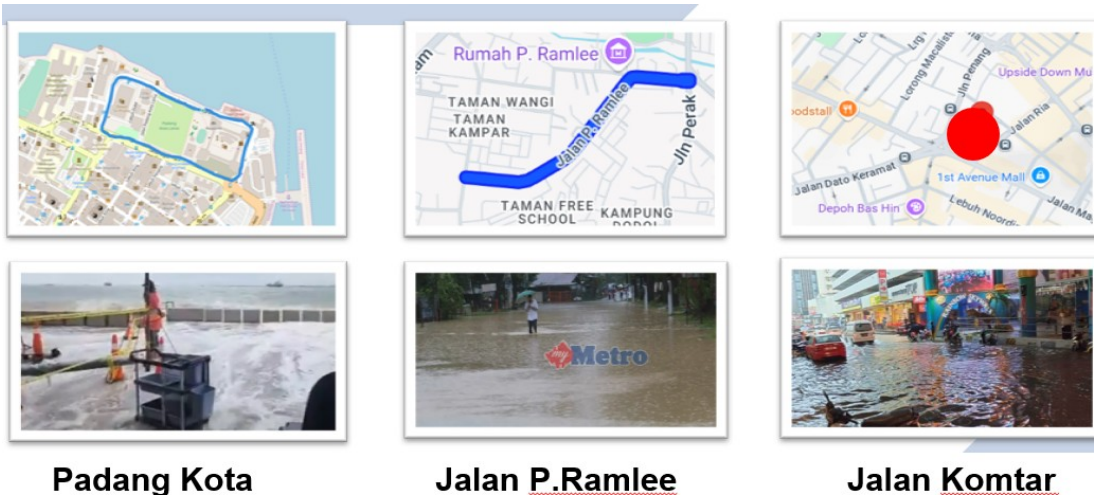


Figure 1.0 Three Case Studies that happen flash floods

A. Case Study 1 (2018) – Padang Kota

In 2018, Padang Kota, a popular and scenic waterfront area in Georgetown, Penang, was severely affected by coastal flooding. The likely causes included a combination of high tides, storm surges, and prolonged heavy rainfall, all of which contributed to the overwhelming of the area's drainage system. The image from the incident shows water being actively pumped out by local authorities, indicating that the existing drainage infrastructure was not capable of handling the excess water on its own. This situation reflects a broader vulnerability faced by low-lying coastal areas, where the combination of natural tidal forces and inadequate drainage capacity can easily result in flooding. The problem is further intensified by the ongoing effects of climate change, such as rising sea levels and the increasing frequency of extreme weather events. These factors put additional stress on drainage systems that were not originally designed to cope with such pressures. The case of Padang Kota highlights the urgent need for coastal flood mitigation measures, including improved drainage systems, tidal gates, and adaptive infrastructure that can respond to both marine and urban runoff.

B. Case Study 2 (2022) – Jalan P. Ramlee

In 2022, Jalan P. Ramlee, a known flood-prone area in Georgetown, experienced severe flash flooding that disrupted daily activities and posed risks to both property and public safety. The primary cause of the flooding was intense and sustained rainfall, which quickly overwhelmed the outdated and insufficient drainage infrastructure. The image captured from the event shows high water levels submerging roads and affecting nearby buildings, suggesting that the drainage system was either clogged, undersized, or poorly maintained. The topography of Jalan P. Ramlee, which naturally collects runoff from surrounding areas, further contributed to water accumulation. This incident occurred during a period when Penang was facing several similar urban flooding events, pointing to a systemic issue with stormwater management across the city. The case underscores the need for significant infrastructure upgrades, including wider and deeper drains, regular maintenance schedules, and the integration of sustainable urban drainage systems (SUDS) such as detention basins and permeable pavements. Without such improvements, the area remains vulnerable to recurring flash floods with potentially worsening impacts.

C. Case Study 3 (2023) – Jalan Komtar

In 2023, Jalan Komtar, located in the heart of Georgetown and known for its high-density commercial and pedestrian traffic, was hit by sudden and severe urban flash flooding. This incident was largely driven by heavy rainfall that quickly overwhelmed the local drainage systems. Images from the event show streets heavily submerged, with vehicles stalled and pedestrians stranded—clear indicators of drainage system failure. The flooding in Jalan Komtar revealed several key issues: the drainage system was likely clogged due to lack of maintenance, the existing infrastructure was not built to accommodate the volume of runoff generated by such intense rain, and the rapid pace of urban development had reduced the availability of green spaces and permeable surfaces that help absorb rainwater. The situation highlights a growing trend in urban areas, where increased surface runoff from concrete-heavy landscapes and outdated infrastructure cannot keep up with the intensity and frequency of extreme weather events. The consequences are not only physical but also economic and social, affecting business operations, traffic flow, and public safety. Jalan Komtar's case emphasizes the urgent need for

comprehensive flood mitigation strategies, including infrastructure redesign, better drainage planning, and climate-resilient urban development.

IV. RESEARCH METHODOLOGY

Table 1.0: Research method uses to fulfil the research objectives

Objective	Method(s) Used	Purpose / Contribution
1. To study the types of rainwater harvesting drainage systems in Georgetown.	- Observation of drainage systems	To identify the types and structural characteristics of existing rainwater harvesting and drainage systems currently used in different parts of Georgetown.
2. To measure the workability of the current drainage system and its effectiveness in managing water flow during heavy rains.	- Field observation of flood-prone areas- Questionnaire survey with residents affected by flooding	To assess how well the current drainage system functions during peak rain events, and to gather first-hand data from residents who have experienced flooding.
3. To suggest the best design of rainwater drainage system to enhance water management in reducing flash floods.	- Interviews with experienced MBPP stakeholders (e.g., engineers, urban planners)	To gain expert insights on system design, limitations, and suggestions for improvements, helping to propose an optimal drainage solution for the city.

This research utilizes a mixed-methods approach to address its three core objectives, combining observational, survey, and interview techniques. To achieve the first objective of identifying the types of rainwater harvesting drainage systems in Georgetown, systematic observations of existing drainage infrastructure will be conducted, focusing on system types, structural features, and their spatial distribution. The second objective, assessing the functionality and efficiency of the current drainage system in managing stormwater during peak rainfall events, will be addressed through field observations in flood-prone areas and the administration of structured questionnaires to residents who have experienced flooding. These methods will provide empirical data on system performance under real-world conditions. For the third objective, aimed at recommending an optimal drainage system design to mitigate flash floods, semi-structured interviews will be conducted with key stakeholders from the Penang Island City Council (MBPP), including urban planners and drainage engineers, to gain expert insights into existing system limitations and potential improvements. Collectively, these methods will generate both qualitative and quantitative data, offering a comprehensive assessment of Georgetown’s drainage infrastructure and informing future flood management strategies.

IV. RESEARCH FRAMEWORK

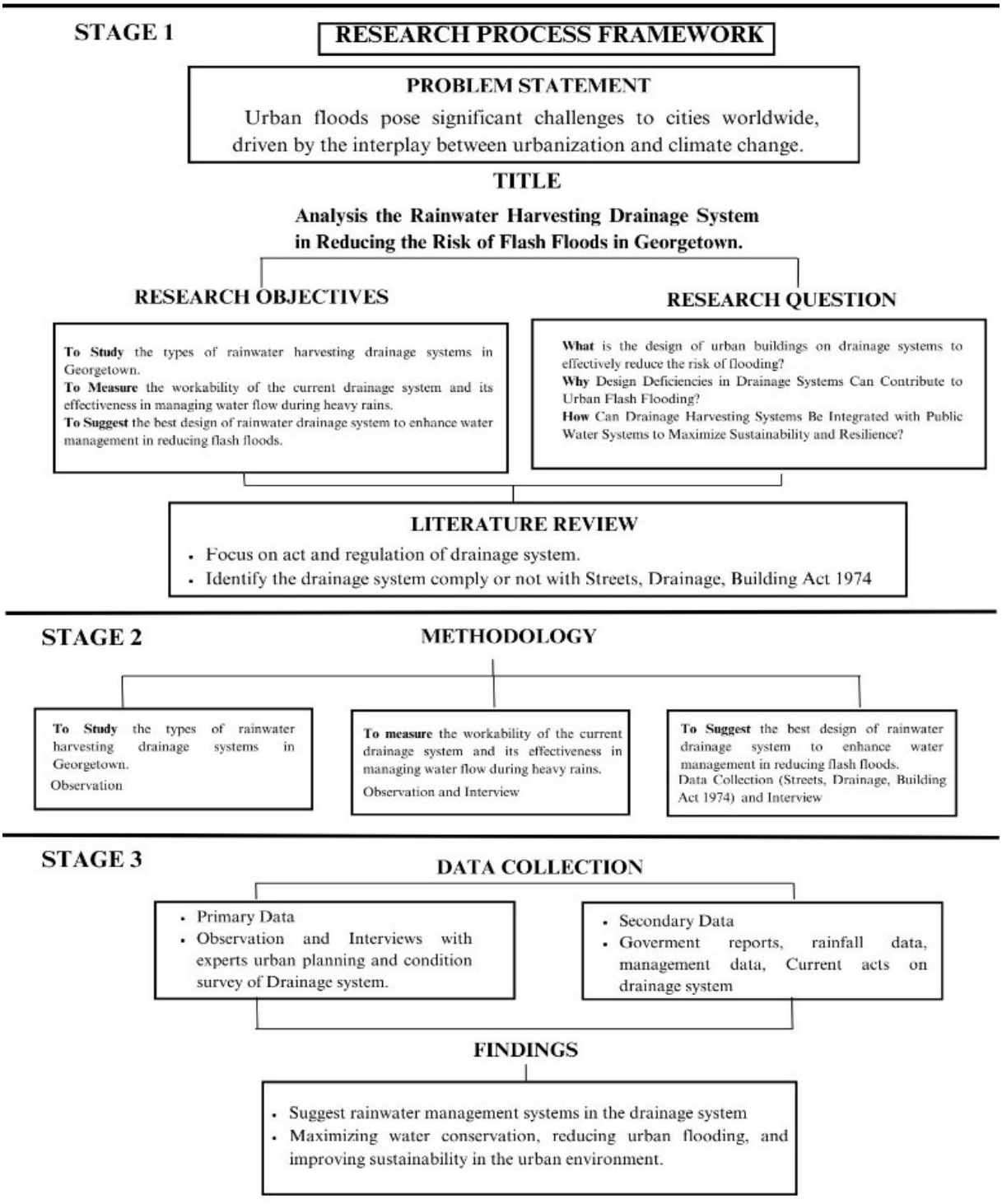


Figure 2.0: Flow of the Research Framework

The Flow of This Research

The research follows a structured three-stage process to analyse the effectiveness of rainwater harvesting drainage systems in reducing flash floods in Georgetown. It begins with Stage 1, where the problem statement is identified, emphasizing the impact of urbanization and climate change on flooding. The research objectives focus on studying different drainage systems, measuring their efficiency, and suggesting improvements. Research questions explore drainage design, system deficiencies, and integration with public water systems. A literature review is conducted to examine relevant laws, particularly the Streets, Drainage, and Building Act 1974, to assess whether existing systems comply with regulations. Moving into Stage 2, the methodology aligns with these objectives by employing observations to study drainage systems, interviews and observations to measure system efficiency, and regulatory analysis to propose better designs. Stage 3 involves data collection from both primary sources, such as expert interviews and field observations, and secondary sources, including government reports, rainfall data, and drainage regulations. The findings suggest integrating rainwater harvesting into urban drainage systems to enhance flood resilience, reduce waterlogging, and support sustainable urban planning. This structured flow ensures a comprehensive approach to assessing and improving urban drainage infrastructure.

CONCLUSION

At the conclusion of this study, the researcher aims to fulfill all the objectives required to address the core purpose of this paper. One of the primary objectives is to develop a cost-effective and efficient rainwater management system for urban buildings to mitigate the risks associated with flash floods. Through a comprehensive analysis of existing drainage systems, identification of operational deficiencies, and exploration of innovative solutions such as green infrastructure, this study will demonstrate how optimized design strategies can enhance water retention and improve stormwater runoff management. The integration of rainwater harvesting systems with traditional drainage infrastructure is emphasized, particularly as a means to improve system performance in response to the compounded challenges of climate change and urbanization. The findings underscore the importance of sustainable, retrofit-friendly solutions that minimize environmental impact while providing resilient flood control.

This research provides valuable insights for urban planners, architects, and policymakers in designing resilient, flood-resistant urban buildings. By offering data-driven recommendations, it aims to support the development of policies that promote sustainable urban planning and effective flood mitigation strategies. Economically, the research advocates for cost reductions through the minimization of flood-related damages and a decrease in reliance on municipal water supplies, benefiting both residential and commercial sectors. In terms of infrastructure, the study highlights the critical need for enhancing urban resilience by improving drainage efficiency and ensuring the long-term sustainability of urban water systems.

Furthermore, by advancing the integration of rainwater harvesting into urban drainage systems, this research contributes to the broader goal of improving urban water management, enabling cities to better adapt to extreme weather events and reduce the environmental impact of excessive surface runoff. The researcher hopes that the findings will catalyze the broader adoption of rainwater harvesting systems in urban developments, fostering the creation of more sustainable and flood-resilient cities. Additionally, this study is intended to inspire future research and innovations that continue to enhance urban water management strategies in response to the ongoing challenges posed by climate change and rapid urbanization.

ACKNOWLEDGMENT

The author sincerely expresses gratitude to the Building Surveying Department of UiTM Perak Branch and the organiser (RISM) and thank to all the people involve, especially the research supervisor, for their invaluable guidance, encouragement, and funding of this publication. Their support has been instrumental in shaping the study and ensuring its quality. Appreciation is also extended to colleagues and peers for their insightful discussions, as well as to urban planners and drainage engineers who contributed valuable expertise through interviews. Their input has greatly enriched the research findings. Lastly, heartfelt thanks go to family and friends for their unwavering support and motivation, which played a crucial role in completing this work. This research is dedicated to advancing sustainable urban water management solutions.

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MODERN SLAVERY IN THE CONSTRUCTION INDUSTRY: ASSESSING MALAYSIA'S CONSTRUCTION STAKEHOLDERS' AWARENESS AND READINESS

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ABSTRACT

Modern slavery, encompassing child labour, debt bondage, forced labour, and human trafficking, continues to penetrate labour-intensive industries globally, including Malaysia's construction sector. Despite international and national legal frameworks, enforcement remains inconsistent and perpetuates exploitative labour practices. There is also a lack of comprehensive awareness among the Malaysian construction industry's stakeholders, including project managers, site managers, contractors, subcontractors, and NGOs, about the prevalence of modern slavery within the sector. Another issue is the uncertainty surrounding the readiness of Malaysia's construction industry stakeholders to address and combat modern slavery practices within the sector effectively. Migrant workers, who make up a significant portion of the industry, are particularly vulnerable to exploitative labour conditions due to weak regulatory enforcement and opaque supply chains. Using a conceptual approach, this study also explores existing legal frameworks, industry challenges, and the role of corporate and governmental interventions. With the focus on Malaysia's construction industry stakeholders, this paper intends 1) to evaluate the current awareness of modern slavery practices and implications among key stakeholders in Malaysia's construction industry and 2) to examine the readiness of stakeholders to recognise and address modern slavery in the construction industry. Through a quantitative approach based on surveys distributed to construction stakeholders, the collected data will be analysed using descriptive statistics to identify awareness levels and readiness gaps. This research addresses a critical knowledge gap by focusing on the Malaysian construction industry's stakeholders' ability to recognise and address modern slavery practices. Eventually, this research aspires to inform policymakers and industry leaders about the gaps in awareness and readiness, offering practical recommendations for creating targeted interventions.

Keywords: Modern Slavery, Malaysia's Construction Stakeholders, Malaysia's Construction Industry, Awareness, Readiness

I. INTRODUCTION

Modern slavery is a serious problem affecting millions of people worldwide. It includes child labour, debt bondage, forced labour, and human trafficking (Anti-Slavery International, 2024; Monciardini et al., 2019). Many industries, especially those that require a lot of manual work, such as construction, are heavily impacted by modern slavery. Victims often suffer from restricted freedom, threats, and financial exploitation. It is a systemic issue in both developed and developing countries, leading to widespread socio-economic challenges. Vulnerable groups, such as migrant workers and those with little education or legal knowledge, are at a higher risk (Flynn & Walker, 2020). Multinational corporations often relocate exploitative labour practices to countries with weaker regulatory environments, where lower labour standards enable cost-cutting at the expense of workers' rights (Strand et al., 2023).

Modern slavery is common in places that rely heavily on migrant workers, like the Middle East and South Asia, where systems such as the kafala system make abuse easier (States, 2015). Many migrants move in search of jobs due to the high demand for cheap labour in large projects like stadiums and megadevelopments, but they often face poor working conditions (Shepherd, 2021). Their situation is worsened by low education levels, lack of legal knowledge, and dependence on employers for work permits and housing (Moyce & Schenker, 2018), which leaves them with little power to speak out or leave.

Modern slavery happens when people are forced, tricked, or pressured into working in harsh conditions (Dowlah, 2021). Methods like holding back wages, taking workers' ID documents, and charging high recruitment fees mostly affect migrant workers and trap them in abuse and dependency (Types of Modern Slavery, 2025). If they try to leave, they may be treated as illegal migrants or threatened with violence. Fear, lack of awareness, and limited legal help stop many from reporting their abuse, letting modern slavery continue without much notice from authorities or stakeholders.

Acts about Modern Slavery in Malaysia

The Employment Act 1955 (Act 265) is Malaysia's main labour law, regulating wages, working hours, and employment contracts to prevent exploitation. Section 90B criminalises forced labour with penalties, including fines and imprisonment. The Act also requires written employment contracts to prevent deceptive recruitment and mandates employers to report the hiring and termination of foreign workers to curb labour trafficking. However, enforcement remains weak, with issues like wage theft, contract substitution, and limited access to justice for foreign workers still widespread. The Children and Young Persons (Employment) Act 1966 (Act 350) helps prevent child labour in industries like construction. The Act also restricts employment in risky industries to protect young workers. Employers who violate these rules face legal penalties.

The Employees' Minimum Standards of Housing, Accommodations, and Amenities Act 1990 (Act 446) ensures proper housing for workers, especially in construction. Employers must provide adequate living conditions, including clean water, electricity, and sanitation. However, non-compliance is common, leaving many workers in poor living conditions that increase their vulnerability to exploitation. The Anti-Trafficking in Persons and Anti-Smuggling of Migrants Act 2007 (Act 670) targets trafficking and forced labour in construction. Trafficking involving labour exploitation is punishable by up to 15 years in prison and heavy fines. Victims are entitled to protection and rehabilitation. Despite strong legal measures, identifying victims and prosecuting traffickers remains difficult, as victims often fear retaliation or deportation.

Problem Statements

The construction industry, worldwide, lacks awareness of modern slavery among stakeholders, including project managers, site managers, contractors, subcontractors, policymakers, and NGOs. This issue stems from reliance on low-skilled labour, limited supply chain transparency, and strict project deadlines, which increase the risk of exploitation (Jelenic, 2023). Another issue is stakeholders' lack of readiness to combat modern slavery. Many lack structured training, making them unprepared to implement anti-slavery measures (Dowlah, 2021). Inconsistent regulation enforcement and weak industry support further prevent a unified response (Dodd et al., 2022). Without targeted initiatives, stakeholders may struggle to align their practices with ethical and legal standards (Strand et al., 2023). Despite growing global efforts to address this issue, many stakeholders in Malaysia remain uninformed about its existence and the severe implications for workers' rights and well-being (Nizam, 2023). The industry's stakeholders also lack the necessary knowledge to identify indicators of exploitation and are uncertain about their roles in addressing these issues (Nizam, 2023). This knowledge gap hinders the implementation of effective measures to identify and mitigate risks within the industry. There is no clear extent to how deeply the Malaysian construction industry's stakeholders understand the implications of modern slavery on ethical practices, worker rights, and legal compliance.

Aims & Objectives

While previous studies have explored the general awareness of modern slavery, limited research has specifically addressed the level of readiness among Malaysian construction stakeholders. This research aims to assess the awareness and readiness of stakeholders in Malaysia's construction industry to recognise and address issues related to modern slavery. To accomplish the aim, the objectives of this research are to evaluate the current awareness of modern slavery practices and implications among key stakeholders in Malaysia's construction industry and to examine the readiness of stakeholders to recognise and address modern slavery in the construction industry.

Research Significance

This research is geographically limited to Malaysia and focuses specifically on the construction industry, where issues of modern slavery are increasingly pertinent yet underexamined. This study centres on gathering insights from key personnel about their level of awareness of modern slavery practices in Malaysia's construction industry and their industry-wide efforts to combat the issue. The targeted respondents consist of stakeholders from companies, including project managers, site managers, contractors, subcontractors, policymakers, NGOs, and others who are directly or indirectly involved in labour management. The research provides both theoretical and practical contributions that can drive ethical labour practices and policy improvements.

i) Theoretical Significance - From an academic perspective, this study expands the body of knowledge about modern slavery within the construction industry. While global research has extensively examined forced labour in various industries, there is limited empirical data on the specific challenges faced by Malaysia's construction stakeholders. By focusing on awareness and readiness, this study introduces a framework for assessing the industry's capacity to combat modern slavery. Furthermore, the research bridges gaps in the existing literature by explaining how awareness pertains to recognising modern slavery as an issue and diving deeper into the knowledge of its legal, ethical, and operational implications. Readiness, on the other hand, evaluates stakeholders' willingness and ability to take concrete action against exploitative labour practices. By systematically assessing these two dimensions, the study offers a nuanced perspective that contributes to both academic discourse and policy formulation. Additionally, this research informs discussions on legal and policy interventions. Malaysia has existing labour laws, such as the Employment Act 1955 and the Anti-Trafficking in Persons and Anti-Smuggling of Migrants Act 2007, yet their enforcement remains inconsistent. By identifying gaps in stakeholder knowledge and regulatory compliance, this study supports the refinement of existing laws and alignment with international frameworks such as the United Nations Sustainable Development Goals (SDG 8.7) and International Labour Organization (ILO) conventions.

ii) Practical Significance - Beyond theoretical contributions, the study offers practical insights that can drive change in Malaysia's construction industry. One of its primary contributions is enhancing industry-wide awareness of modern slavery. Many stakeholders lack adequate knowledge about forced labour and its legal consequences. By highlighting these gaps, the study serves as a foundation for industry-wide training programmes and ethical guidelines that promote responsible labour practices. Moreover, the research points out the value of regulatory compliance and enforcement. It identifies weaknesses in Malaysia's current labour governance framework and provides actionable recommendations for improving monitoring mechanisms. Strengthening regulatory oversight can ensure better compliance with national and international labour standards and reduce the risk of legal and reputational consequences for construction firms. The study also addresses stakeholder readiness by proposing targeted capacity-building initiatives. Many industry players, particularly small and medium-sized contractors, lack structured training and resources to identify and prevent modern slavery. By developing industry-specific interventions, such as workshops, reporting mechanisms, and collaborative platforms, this study helps improve the construction industry's ability to recognise and mitigate exploitative labour conditions. Furthermore, this research contributes to sustainable and ethical construction practices. Modern slavery not only affects human rights but also has significant economic and reputational risks for businesses. Ethical labour practices enhance productivity, reduce employee turnover, and improve industry credibility. By promoting responsible labour sourcing and transparent supply chains, the study aligns with Malaysia's broader sustainability goals and global corporate social responsibility (CSR) initiatives.

iii) Contributions to the Construction Industry - This study provides several key contributions to the Malaysian construction industry. The research informs policymakers about areas where existing labour laws and regulations require enhancements to ensure better protection for workers and stricter enforcement against exploitative practices. By identifying gaps in awareness and understanding, the study paves the way for industry-wide educational programmes aimed at contractors, developers, and regulatory bodies. Construction firms can use the study's findings to identify vulnerabilities in their labour supply chains and implement stronger due diligence measures to prevent forced labour. As global markets increasingly enforce strict anti-slavery regulations, Malaysia's construction industry must align with international human rights norms. This study reveals how

industry players can comply with global standards, preventing potential trade restrictions or reputational damage.

II. LITERATURE REVIEW

Modern slavery exists in both developed and developing countries, though its forms vary based on economic, social, and political contexts. The Global Slavery Index 2018 identifies the textiles and fashion industry as a major perpetrator worldwide (Business, 2018). In developed countries, strict labour laws, such as the UK Modern Slavery Act (2015) and the U.S. Trafficking Victims Protection Act (2000), aim to combat forced labour. Migrant and undocumented workers are especially vulnerable due to restrictive immigration policies and weak legal protections. In developing countries, weak governance, economic instability, and global supply chains drive systematic labour exploitation. Industries like construction, garment manufacturing, and mining rely on cheap labour, often under forced conditions (Crane et al., 2021). Poverty, lack of education, and corruption worsen the issue, limiting victims' access to justice (Andrees & Belser, 2022).

Available Research on Modern Slavery

According to MSite (2015), an estimated 50 million people worldwide are trapped in modern slavery, with 122,000 in the UK alone. Despite these numbers, public awareness remains low, and many individuals either fail to recognise the signs or choose to ignore them. The UK Government's Modern Slavery Act 2015 defines modern slavery as involving the recruitment, transportation, harbouring, or reception of people by any means with the intent of exploitation. Forced labour is the most prevalent form of modern slavery in the construction industry. Unskilled workers are often brought to construction sites and made to perform jobs without proper training. Contrary to common assumptions, such workers are not necessarily kept in physical captivity. Instead, unlicensed gangmasters control them by withholding wages, deducting excessive fees for tools and clothing, or imposing other financial constraints (MSite, 2015).

A case study from the UK highlights how modern slavery is embedded within certain criminal family firms. Coercive power, symbolic violence, and misrecognition are key mechanisms that trap individuals in exploitative labour conditions. Employers in these firms exert psychological control over workers, which promotes a feeling of dependence and indebtedness that prevents them from escaping abuse (Salmon, 2020). This manipulation is often reinforced by cultural and social pressure, language barriers, and threats of violence, making it difficult for victims to seek help or recognise their situation as forced labour. These instances highlight the intricacy of contemporary slavery when psychological and financial restraints frequently take the place of physical coercion. The shrimp industry in Thailand heavily relies on trafficked labourers, many of whom are recruited from poorer neighbouring countries, such as Myanmar and Cambodia, with deceptive promises of stable employment. Upon arrival, these workers become victims of debt bondage and are forced to labour under extreme conditions without proper compensation. Reports indicate that workers are subjected to excessive working hours, physical abuse, and threats of violence, effectively trapping them in a cycle of exploitation (Pathmanathan, 2020). Despite growing global awareness of these abuses, these exploitative practices are nonetheless supported by the ongoing demand for cheap seafood, especially from wealthy countries (Crane et al., 2021).

Similarly, domestic workers in Malaysia, predominantly migrants from Indonesia, Vietnam, and the Philippines, frequently endure abusive conditions. Many live in their employers' homes, where they are exposed to physical and emotional abuse, food deprivation, excessive working hours, and wage withholding (Pathmanathan, 2020). The absence of robust legal protections for migrant domestic workers exacerbates their vulnerability, leaving them without access to legal recourse or support services (LeBaron & Kyritsis, 2022). Although Malaysia has taken steps to strengthen labour protections, enforcement remains inconsistent, and many cases of exploitation go unreported due to retaliation or deportation (ILO, 2021).

Types of Modern Slavery

Child labour robs children of their childhood, education, and development. According to the International Labour Organization (ILO) Conventions No. 138 (1973) and No. 182 (1999), it includes work that harms children physically, mentally, or socially and interferes with their schooling. These children often face long hours, low wages, dangerous conditions, and limited education, affecting their future opportunities (Dowlah, 2021). While it is rare in construction, child labour exists on plantations, in informal jobs, and at home (Dowlah, 2021). Despite Malaysia's ratification of child protection laws, their enforcement remains weak due to poverty, a lack of education, and legal gaps. The Children and Young Persons (Employment) Act 1966 restricts child labour, but enforcement is weak, especially for undocumented children (SUHAKAM, 2023). Malaysia's National Action Plan on Child Labour (NAPCL) aims to eliminate child labour, but gaps in enforcement, limited resources, and economic pressures slow progress (ILO, 2022). A major challenge is the informal nature of these industries, where

unregistered workers make regulation difficult. Child labour in family businesses also goes undetected, complicating enforcement (SUHAKAM, 2023).

Debt bondage is a form of modern slavery where workers are trapped in exploitative jobs to repay debts. Recruitment agencies often charge excessive fees, while employers impose illegal wage deductions or confiscate identification documents, making escape nearly impossible (Liu et al., 2022). This practice is common in construction, agriculture, domestic work, and fishing, particularly in Southeast Asia, South Asia, the Middle East, and Europe. Foreign workers in Malaysia's construction industry frequently fall into debt bondage. Many borrow USD 2,000–5,000 for recruitment fees, struggling to repay due to low wages and unfair deductions (ILO, 2021). Workers arrive expecting fair pay but must first settle high agency debts (Liu et al., 2022). Employers cut wages for food, accommodation, and transport, delaying debt repayment (SUHAKAM, 2023). Employers prevent workers from leaving for better jobs (ILO, 2021). Malaysia's Employment Act 1955 bans unlawful wage deductions, but weak oversight allows unethical recruitment practices to continue.

The International Labour Organization (ILO) defines forced labour as work performed under coercion, threats, or deception, where individuals cannot leave freely (ILO, 2023). It affects millions globally, particularly migrant workers in construction, agriculture, and manufacturing (Benstead et al., 2020; Monciardini et al., 2019). In construction, workers often face exploitation due to limited legal protections and complex supply chains (Jelenic, 2023; Liu et al., 2022). Malaysia heavily relies on migrants from Indonesia, Bangladesh, Nepal, and Myanmar, many of whom are subjected to forced labour. Common issues include employers and recruiters withholding workers' passports and restricting their movement (ILO, 2022). Workers face threats of deportation or physical abuse to force compliance. Many migrant workers arrive in Malaysia with heavy recruitment debts, trapping them in exploitative conditions. Employers frequently confiscate passports and delay wages, creating financial and legal dependency. Workers also face unsafe conditions, with high rates of workplace accidents due to poor safety protocols (Verité, 2020). These conditions led the U.S. Department of Labor to classify Malaysia's construction sector as high-risk for forced labour.

Human trafficking affects millions globally across industries such as agriculture, domestic work, manufacturing, and construction. The UN Palermo Protocol (2000) defines human trafficking as the recruitment, transportation, or harbouring of individuals through threats, coercion, fraud, or deception for exploitation. This often results in forced labour, debt bondage, and severe workplace abuse. Malaysia is both a destination and transit country for trafficked workers, particularly from Indonesia, Bangladesh, Nepal, and Myanmar. Many are deceived by recruiters with false promises of high wages and decent work but end up in abusive conditions (Jelenic, 2023). Workers pay excessive recruitment fees only to find different job conditions upon arrival (ILO, 2022). Large projects often rely on subcontractors who employ trafficked workers under harsh conditions (SUHAKAM, 2023). Workers often live in overcrowded, unsanitary shelters near construction sites (ILO, 2023). Human trafficking remains a major global issue, particularly in construction, manufacturing, agriculture, and domestic work. While legal frameworks exist, enforcement gaps and corruption continue to fuel exploitation.

Awareness & Readiness

Awareness is the ability to perceive, recognise, and acknowledge information about a particular issue, concept, or phenomenon (Gafoor, 2012). It serves as the foundation for deeper understanding and action, making it a crucial element in addressing social issues such as modern slavery. Cognitive awareness, also known as metacognition, refers to an individual's ability to reflect on their knowledge and learning process (Papaleontiou-Louca, 2003). Various methods, such as surveys, scenario-based assessments, and observational techniques, are employed to measure cognitive awareness of social issues like modern slavery (Hughes, 2019; Nilsson et al., 2011). These tools assess individuals' ability to understand, identify, and apply knowledge, offering insights into their level of awareness.

The importance of awareness is evident in driving change across different sectors. In healthcare, awareness of medical conditions like diabetes and mental health disorders encourages early intervention and treatment (Glanz 2022). Specifically, in the context of modern slavery in the construction industry, awareness plays a critical role in identifying exploitative labour practices and understanding their consequences. Without awareness, individuals may remain passive or oblivious to pressing issues, reducing the likelihood of meaningful action. Therefore, fostering awareness at multiple levels is essential in promoting social responsibility, informed decision-making, and collective efforts toward addressing global challenges.

Readiness is a crucial factor in determining an individual's ability to respond effectively to challenges, opportunities, and unforeseen circumstances (Jones & Smith, 2020). It encompasses physical, mental, and

emotional preparedness, influencing success and resilience across personal, professional, and societal domains. Within this research, readiness specifically refers to stakeholders' ability to implement anti-slavery measures, including policy adoption, training initiatives, and adherence to ethical standards. Measuring readiness involves several assessment tools, such as organisational readiness surveys, pilot studies, and capacity evaluations. Organisations invest in infrastructure, financial planning, and contingency measures to ensure stability during disruptions (Kirkpatrick & Kirkpatrick, 2018), while individuals who save money and plan demonstrate financial readiness in their personal lives.

Readiness is essential because awareness alone is insufficient without the capability and willingness to act. A well-prepared approach enables individuals and organisations to handle challenges proactively rather than reactively, ensuring efficient problem-solving and adaptability (Brown, 2019). In professional settings, employees who are ready for change can efficiently perform their tasks and adjust to evolving work environments. For instance, businesses that anticipate market fluctuations can swiftly implement strategies to mitigate risks and seize new opportunities. In education, students who engage in regular study habits and seek additional knowledge are better prepared for academic success and future careers (Robbins et al., 2020). Similarly, employees who continuously upgrade their skills and stay informed about industry advancements enhance their employability and career growth prospects (Schwartz, 2017). Crisis management further highlights the importance of readiness, as governments and organisations with disaster preparedness plans can respond more effectively to emergencies while minimising damage and ensuring public safety (WHO, 2021).

III. METHODOLOGY

A comprehensive literature review is conducted using academic databases such as ScienceDirect, Elsevier, and Google Scholar to understand the issue of modern slavery. This study, then, will employ a quantitative research method, where data generated from the literature survey will be further developed into a structured questionnaire. A structured questionnaire comprising a mix of multiple-choice (Yes or No) and Likert-scale questions has been designed to collect quantifiable data regarding stakeholders' awareness and readiness to address modern slavery issues. The goal is to ensure structured and quantifiable responses. By analysing their responses in measurable terms, this design shall provide valuable insights into stakeholders' awareness and readiness to address modern slavery issues. Since this research is currently structured as a conceptual paper, it does not yet include primary data.

At present, data collection has not yet been conducted, as the study is in the process of recruiting suitable respondents to complete the survey. The inclusion of the questionnaire in this paper serves to illustrate the intended research design and data collection method for future empirical analysis. By presenting the survey structure and objectives, this paper lays the groundwork for a subsequent, data-driven investigation. Once responses are gathered and analysed, the findings will contribute to a clearer understanding of stakeholder behaviour and perceptions regarding modern slavery in Malaysia's construction industry.

CONCLUSION

Modern slavery is a worldwide issue. However, many are unfamiliar with the signs of exploitation, and few have policies or training in place to prevent it. Tackling this issue is essential for protecting vulnerable workers and aligning the industry with international labour standards and sustainability goals. The study examines the awareness and readiness of stakeholders in Malaysia's construction industry to recognise and address issues related to modern slavery. This study, employing a quantitative approach, restricts its sample to selected stakeholder groups in the construction industry and relies on self-reported data. In addressing modern slavery within Malaysia's construction industry, this study offers both theoretical and practical contributions that drive academic, policy, and industry advancements. Theoretically, it fills gaps in research by introducing a structured framework for assessing awareness and readiness. Practically, it supports the development of targeted interventions that enhance stakeholders' knowledge, improve regulatory enforcement, and promote ethical labour practices. By contributing to policy formulation, stakeholder engagement, and sustainable construction, this study plays a crucial role in fostering a more responsible and humane industry landscape. Future research should include diverse stakeholders, explore qualitative insights, and assess the effectiveness of current legal and organisational frameworks. In conclusion, the findings from the literature review indicate that there is an urgent need for targeted awareness campaigns, structured training, and stronger enforcement to combat modern slavery issues in the industry. Bridging the gap between awareness and action can help build a more ethical and socially responsible construction sector in Malaysia.

ACKNOWLEDGMENT

The author acknowledges the guidance and support provided by thesis supervisor, Professor Sr. Dr. Mastura Jaafar@Mustapha from Universiti Sains Malaysia.

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DETERMINING THE BENEFITS AND RISKS OF IMPLEMENTING A SMART BUILDING SYSTEM FOR OFFICE BUILDING IN KUALA LUMPUR

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ABSTRACT

Smart Building Systems (SBS) are transforming the built environment by combining cutting-edge technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Building Automation System (BAS) to reduce energy consumption, increase operational efficiency, and improve occupant comfort. The adoption of SBS in office buildings is increasing in Malaysia, particularly in Kuala Lumpur, because of its potential to assist sustainability goals and cost efficiency. However, despite these benefits, high initial costs, operational complexity, and privacy concerns have prevented their widespread adoption. The purpose of this study is to determine the benefits and risks of implementing SBS in office buildings in Kuala Lumpur. A quantitative research approach is employed, involving a structured questionnaire survey distributed to property managers, facility managers, and those involved in managing office buildings that implement SBS. Data will be analyzed using descriptive and inferential statistical approaches to discover relevant patterns and relationships. The findings will provide vital information on the effectiveness of SBS in enhancing building performance, energy efficiency, and occupant well-being while focusing on adoption risks and barriers. The significance of this study is likely to help policymakers, property managers, and industry stakeholders strategize the future growth of smart buildings in Malaysia.

Keywords: Smart Building Systems, Energy Efficiency, IoT, Artificial Intelligence, Office Buildings in Malaysia

I. INTRODUCTION

Smart Building Systems (SBS) are sophisticated frameworks intended to improve building operations' sustainability, comfort, and efficiency through automation and intelligent management. Most new buildings are implemented with SBS such as residential, offices, and retail buildings. Functionally, to maximize building performance and user experience, these systems incorporate several technologies, such as artificial intelligence, Building automation systems, and the Internet of Things (IoT). These systems facilitate intelligent operations, including optimal scheduling, monitoring, and control of building facilities, enhancing safety and recovery readiness (Lam, 2022). Baharudin (2021) describes smart buildings as structures equipped with Building Energy Management Systems (BEMS), which allow for efficient energy consumption through features like lighting control strategies. These systems ensure that energy is used only when needed, reducing overall consumption and greenhouse gas emissions. Besides the benefits, implementing smart building systems in Malaysian office buildings involves substantial initial costs, encompassing the installation of advanced sensors, IoT devices, automation tools, and the integration of intelligent management systems. Retrofitting existing structures to accommodate these technologies further escalates expenses. Additionally, the need for specialized training for operational staff contributes to the financial burden (Hojjati, 2016). Even so, the rate of adoption of smart building technology in Malaysia is still slow compared to more developed markets. Challenges such as high initiation, limited awareness, and lack of manpower are major obstacles to widespread integration (Mee San, 2021).

Therefore, this research has proposed three research questions, firstly, what technology integration is used in smart building systems for office buildings? This is to identify the technology integration used in smart building systems for office buildings. Secondly, what are the benefits of implementing a smart building system for office buildings?

This is to determine the benefits of implementing a smart building system for office buildings. Thirdly, what are the risks of implementing a smart building system for office buildings? This is to determine the risks of implementing a smart building system for office buildings. The research aims to determine the level of benefits and risks of implementing a smart building system for office buildings in Kuala Lumpur.

Furthermore, this research holds significant value in the field of building management and smart city development. Firstly, it provides insights into the technologies utilized in smart building systems, such as Building Management Systems (BMS) and the Internet of Things (IoT), specifically for office buildings. Secondly, it helps distinguish between buildings equipped with smart systems and those that still rely on traditional management methods. Thirdly, the findings of this study serve as a guide for building owners and facility managers in evaluating the advantages and challenges of smart building adoption. Ultimately, this research supports the efforts toward smart and sustainable urban development in Kuala Lumpur, aligning with government initiatives to enhance energy efficiency and optimize building management.

II. LITERATURE REVIEW

A. Definition of Smart Building.

Smart Buildings have been studied and developed for the past three decades, but in more recent literature, office buildings have also started to receive more attention. This seems to be the case in all aspects of the built environment sector likely smart sensors, smart materials and smart meters in buildings. According to A.H. Buckman M, 2014 state smart buildings are intelligent buildings with integrated aspects of enterprise, control and materials and construction, implemented both individually and as a system to be adaptable. Smart Buildings are occupant-based, creating active participants (Brown et al., 2009) by incorporating feedback both to and from occupants about their building use, alongside providing methods for inherent control through integrated enterprise and intelligent systems. The building empowers the occupants to make their own comfort decisions whilst maintaining regulated control. When this manual control is not possible, the occupant should be informed.

A smart building system integrates advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Building Automation System (BAS) to optimize energy efficiency, security, and occupant comfort (Zhou, 2022). These systems rely on interconnected sensors and automation to monitor and control various building functions, including lighting, heating, ventilation, and air conditioning (HVAC) (Ahmad, 2021). The adoption of smart building systems has been driven by the need for sustainability, cost savings, and improved operational efficiency, particularly in urban environments where resource management is crucial (GhaffarianHoseini, 2019).

While the concept of smart buildings is well-defined in terms of technology and functionality, there is still no universally accepted definition. The interpretation of what constitutes a smart building can vary, influenced by differing standards and criteria across academic and industry perspectives (Borhani et al., 2022). This variability highlights the evolving nature of smart building technologies and the need for ongoing research and standardization efforts.

B. The Technology Integration Used in Smart Building for Office Building.

In recent years, the demand for smarter, more energy-efficient office buildings have increased due to growing concerns about sustainability, operational efficiency, and occupant comfort. To meet these expectations, modern office buildings are increasingly adopting smart building systems that integrate various advanced technologies. These technologies work in harmony to automate, monitor, and optimize building operations. This section discusses the key technological components and how they are integrated to create a functional smart building system in office environments. In this paper, the author will focus on Internet of Thing (IoT), Building Automation System, and Artificial Intelligence (AI).

The implementation of Smart Building Systems (SBS) in office buildings involves integrating advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Building Automation Systems (BAS), and data analytics to optimize building operations, reduce costs, and enhance occupant comfort (Jia, 2019). The process typically begins with conducting a needs assessment to identify key objectives, such as energy efficiency, security enhancement, and space optimization (Mohammed, 2021). Based on these objectives, building managers deploy IoT-enabled sensors and automation systems to monitor and control lighting, heating,

ventilation, and air conditioning (HVAC), water management, security systems, and occupancy levels in real time (Ahmad et al., 2021).

C. The Benefits of Implementing a Smart Building System for Office Building.

Adopting smart building systems focus on office building give benefits to the occupants during immerse these technologies. The first benefit of implementing a smart building system is energy efficiency. According to Sovacool and Furszyfer Del Rio, 2019 discovered that smart building's environmental benefits involve reducing greenhouse gas emissions, which is achieved through better monitoring of energy usage and control over carbon emission of CO2 related materials in buildings. In the study conducted by (Froufe et al., 2020), smart building ensures that energy consumed in the building is controlled and monitored in real-time to improve the performance of the building and makes it to be environmentally friendly. As reported in the literature, smart buildings contributed to energy saving and reduced power consumption from 765,228.16 to 499,067.01 kWh, leading a reduction of 34.78% (Lin et al., 2020). Therefore, this study identifies energy saving as a significant benefit of adopting smart building technology in developing countries.

Second benefit are enhancing security and safety of occupants. According to Honeywell and HIS, 2015, the way a building responds to threats, manages access to the facility, secures lives and assets, and makes it comfortable and productive; these are all examples of safety and security systems (illumination, thermal comfort, air quality, connectivity, energy availability). Security and safety in smart buildings are paramount. Humans require complete safety and security, whether the facility is a residential building, office building or commercial building (Berawi et al., 2017). Therefore, safety and security are vital benefits of adopting SBT in developing countries.

Optimizing space utilization also one of the benefits of implementing a smart building system for office. By optimizing space, organizations can reduce the need for excessive square footage, potentially lowering rental or operational costs, especially in high-demand urban areas. Additionally, efficient space usage can support new workplace models such as hot-desking or hybrid work arrangements, improving flexibility and reducing congestion (Honeywell & IHS, 2015). Smart systems also enable dynamic space allocation, where meeting rooms, workstations, and collaboration zones can be reserved or adjusted automatically based on occupancy and scheduling data. This not only improves spatial efficiency but also enhances user experience and supports productivity (Ishmael, Ogara, & Raburu, 2020).

D. The Risks Implementing a Smart Building System for Office Building.

Smart building systems in Malaysia are gaining attention, especially in office buildings, as part of the country's efforts for digital transformation and sustainable urban development. The system integrates advanced technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) to automate building operations, improve energy efficiency, and improve occupant comfort (CIDB, 2024). According to Mee San, (2021) even so, the rate of adoption of smart building technology in Malaysia is still slow compared to more developed markets. Challenges such as high initiation, limited awareness, and lack of manpower are major obstacles to widespread integration.

The first risk of implementing a smart building is high initial cost. The upfront cost of installing smart technologies including IoT sensors, automation platforms, and centralized management systems is significantly higher than traditional systems. This includes hardware procurement, installation, training, and system integration. For example, installing a comprehensive building management system (BMS) for a medium-sized office may cost tens of thousands of dollars, which can be a barrier for adoption (Zhou et al., 2022). This high capital investment may delay return on investment (ROI) and deter small or medium-sized enterprises (SMEs) from implementation.

Second risk is privacy concern among users. Implementing smart building systems involves collecting large volumes of data from occupants, including location, movement, and behavioral patterns. This data, if not properly secured, may be misused or accessed by unauthorized parties, leading to serious privacy violations. For example, motion sensors and biometric access control systems can monitor staff activities in real time, raising ethical and legal questions regarding surveillance (Allam & Jones, 2021). Such invasions of privacy may result in reduced employee trust, dissatisfaction, and potential legal repercussions under data protection laws such as the GDPR.

Complexity in operation is one of the risks of implementing a smart building. Smart building systems often require complex integration of hardware, software, and network components, which can overwhelm building management

teams. Operating such advanced systems demands skilled personnel and specialized training. For instance, a smart HVAC system may involve artificial intelligence algorithms that adjust temperature automatically based on occupancy patterns, which could be difficult to troubleshoot without technical expertise (Kumar et al., 2020). This operational complexity increases reliance on vendors and may lead to underutilization of features.

Dewan Bandaraya Kuala Lumpur (DBKL) has introduced the Kuala Lumpur Low Carbon Building Checklist (KL LCBC 2023) as a guide for the development of low-carbon buildings (DBKL, 2024). This document emphasizes the use of Building Energy Management Systems (BEMS) and smart building data collection to monitor and reduce energy consumption. In addition, iconic buildings such as Exchange 106 at Tun Razak Exchange (TRX) have implemented smart and environmentally friendly technology in their design and operation. The building uses a high-tech cooling system, smart LED lighting, and construction materials that ensure energy efficiency, making it an example of an advanced green building in Kuala Lumpur.

Kuala Lumpur has witnessed a surge in smart buildings, particularly in commercial and office spaces. These buildings utilize interconnected sensors and automation systems to manage lighting, heating, ventilation, air conditioning (HVAC), and security, ultimately reducing energy consumption and operational costs (InvestKL, 2024). For instance, SafeTown, a smart urban development project in Kuala Lumpur, integrates smart hotels, luxury residential towers, office blocks, and retail outlets with IoT-based infrastructure to enhance energy efficiency and urban living experiences (Chiefway, 2024).

III. METHODOLOGY

This research employs a quantitative approach as the appropriate approach for determining the level of benefits and risks of implementing a smart building system for office buildings in Kuala Lumpur. This is due to the research's utilization of structured numerical data or data that can be readily transformed into numerical form. It is a research approach that involves the collection and analysis of numerical data to understand patterns, relationships, or trends. Here is the summary of the research methodology for this research as shown below:

A. Questionnaire Survey

The first phase involves collecting primary data through a questionnaire survey. The sample size is based on Krejcie and Morgan's (1970) table of determining sample size. The target respondents include facility managers, building managers, and property managers who have experience with smart building systems in office settings. The survey is structured to address the three main objectives of the research. The first section is about technology use that integrates with smart building systems. A multiple-choice question will be used. The second section requires the respondents to determine the level of benefits stated in the questionnaire. It same goes with section three, where the respondents are required to determine the level of risks stated in the questionnaire. For sections two and three, Likert scale questions will be used. The total estimated number of smart office buildings in Kuala Lumpur is about 151. According to Krejcie and Morgan (1970), the sample size is 108. The sampling technique used for this research is simple random sampling.

B. Data Analysis

The second phase focuses on analyzing the data collected from the questionnaire. Descriptive statistics will be applied to describe respondents' profiles and percentages of technology used in smart building systems. Inferential statistics will be employed to explore relationships between variables, such as the correlation between the technology used, and the level of benefits and risks. The analysis will show in visual outputs, such as tables and graphs, to present trends and comparisons effectively, offering a comprehensive understanding of the research findings.

CONCLUSION

The implementation of Smart Building Systems (SBS) in office buildings in Kuala Lumpur presents a promising solution for enhancing energy efficiency, optimizing space utilization, and improving occupant safety and comfort. By leveraging technologies such as IoT, AI, and BMS, smart building system can contribute significantly to sustainability goals while reducing operational costs. However, risks such as high initial investment, system complexity, and data privacy concerns remain key barriers to widespread adoption. Addressing these issues through policy incentives, improved data security frameworks, and cost-effective implementation strategies will

be crucial for advancing smart building integration in Malaysia. Future research should explore the long-term cost-benefit analysis of SBS in various commercial settings and investigate adaptive solutions that can further enhance their efficiency. Collaboration between government bodies, industry stakeholders, and technology providers will be essential in accelerating the adoption of SBS and ensuring sustainable urban development.

ACKNOWLEDGMENT

I would like to express sincere gratitude to The Faculty of Built Environment, University Malaya for encouragement throughout this research. Special appreciation is extended to the supervisor, Dr. Zairul Nisham Bin Musa, for his invaluable guidance, constructive feedback, and dedication to overseeing the progress of this study. Additionally, the author acknowledges the contributions of lecturers, and peers who provided insightful discussions and assistance during the research process. The financial support for this publication, provided by the department, is also deeply appreciated. Finally, heartfelt thanks go to family and friends for their unwavering encouragement and motivation throughout this academic journey.

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A CRITICAL INVESTIGATION INTO THE RISK FACTORS LEADING TO GLOBAL CLAIMS IN CONSTRUCTION

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ABSTRACT

The construction industry plays a vital role in economic development but faces significant challenges, particularly in managing contractual disputes. One such dispute arises from 'global claims,' where contractors combine multiple issues into a single claim without specifying individual causes, often leading to legal conflicts and financial uncertainty. This research aims to examine the impact of global claims on project performance. The objectives include (1) identifying the causes of global claims, (2) assessing their effects on project efficiency, and (3) evaluate the roles of Quantity Surveyors in mitigating these risks. A mixed-methods approach is adopted, combining qualitative analysis of literature and case law with quantitative data gathered through structured surveys targeting industry professionals. This paper uses a thematic analysis to identify patterns and underlying factors while incorporating a descriptive analysis to assess the trends, correlations and impact of risk factors. The findings are expected to reveal common triggers of global claims, such as financial risks, supply chain disruptions, and contractual ambiguities. Additionally, the research forecasts that enhanced documentation, improved contractual clarity, and proactive risk management can significantly reduce disputes and improve project outcomes. This study contributes to the construction industry by promoting transparency, reducing disputes, and strengthening the role of Quantity Surveyors in risk mitigation by providing insights into better claim management strategies.

Keywords: global claims, risk factors, construction disputes, claims management

I. INTRODUCTION

1.1 Introduction

A contractual claim is a formal request for payment, clarification, modification of terms, or other remedies under a contract. These claims typically fall into categories such as delays, disruptions, cost overruns, or loss of productivity. A global claim, also known as a composite, total cost claim, or rolled-up claim, arises in construction disputes when a contractor seeks compensation for losses resulting from multiple causes without attributing specific damages to individual breaches (Haidar, 2011, p. 151). Due to their broad nature, global claims can be challenging to verify, often leading to disputes, arbitration, or litigation, which may contribute to project delays, cost overruns, and strained stakeholder relationships.

1.2 Research rationale

Global claims present significant challenges in the Malaysian construction industry, affecting contractors, clients, and stakeholders by consolidating delays, disruptions, and cost overruns into a single claim. While simplifying compensation, these claims often lack clarity, failing to distinguish between external delays, such as client-driven changes, and contractor-related issues like poor planning. This ambiguity leads to disputes, increasing financial, technical, and reputational risks. This research examines the key risk factors behind global claims, including delays, cost overruns, and external influences, and explores strategies to manage and reduce them. Solutions include improved documentation, dispute avoidance mechanisms, and enhanced contract provisions to promote fairness, transparency, and effective claim governance.

1.3 Research questions

What are the key risk factors contributing to the rise of global claims in construction and what are the strategies to better manage and mitigate these claims in reducing the risk and ensuring project success?

1.4 Research aims

The aim of this research is to investigate the risk factors contributing to global claims.

1.5 Objectives

1. To identify the key risk factors that contribute to the occurrence of global claims.
2. Analyze impacts of global claim in overall performance
3. To examine the role of QS in risk mitigation of global claims
4.

1.6 Significance of research

This research aims to benefit key stakeholders in the construction industry, including contractors, clients, Quantity Surveyors, and legal professionals, by enhancing the management of global claims and reducing disputes. It will help contractors and project owners present and assess claims more accurately while strengthening Quantity Surveyors' role in risk mitigation. Legal professionals, contract administrators, and project managers will gain insights into improved dispute resolution and contractual clarity. Additionally, regulators, policymakers, and academics can use the findings to refine industry standards and advance research, ultimately promoting efficiency, transparency, and successful project outcomes.

II. LITERATURE REVIEW

2.1 *Definition of global claims*

Delays in the construction industry frequently result in cost overruns and extensions of time, leading contractors to submit global claims. A global claim consolidates multiple causes of delay or loss into a single claim, making it challenging to distinguish individual contributing factors. Haidar (2011:152) defines global claims as a composite sum covering multiple claims where subdivision is impractical. Contractors often favour global claims as they facilitate compensation without the necessity of isolating specific causes, which may be interrelated or difficult to quantify. However, such claims are frequently contested due to concerns regarding transparency and justification. Keating on Construction Contracts describes global claims as offering "an inadequate explanation of the causal nexus between events/matters relied upon and the alleged loss and damage or delay for which relief is claimed" (Wilkins, 2022). This lack of clarity often renders global claims contentious in construction disputes, complicating resolutions and increasing the potential for legal challenges.

2.2 *Types of global claims*

Global claims in construction fall into two main categories: time and cost, both closely linked. Time-related claims arise from delays, order changes, disruptions, poor management, or external factors like weather, leading to project extensions (Aceris Law LLC, 2022). These claims aim to identify the causes of delays and establish delay periods, though defining cause-effect relationships can be challenging, often resulting in disputes. Cost-related claims focus on financial losses due to delays, disruptions, and other unquantifiable events. When individual causes cannot be isolated, contractors may file a 'total cost claim,' grouping all factors together and potentially escalating disputes (Aceris Law LLC, 2022).

2.3 *Risk factors leading to global claims*

Financial Risks

Financial risks are a significant factor behind global claims in construction projects, often arising from delays, cost overruns, and disruptions that impact project timelines and budgets. Cumulative delays—caused by factors such as change orders, design modifications, approval delays, and site access issues—can escalate over time, making it difficult to identify a single cause. This complexity often leads contractors to submit global claims to recover costs (Haidar, 2011; FTI Consulting, 2023). Concurrent delays, which occur simultaneously due to various reasons like subcontractor issues or material shortages, further complicate the assignment of responsibility and contribute to extended timelines and inflated costs (Aceris Law LLC, 2022). Other financial risks, including labour shortages, supply chain disruptions, and equipment unavailability, also contribute to project delays and increased expenses. A shortage of skilled labour, for example, can lead to reliance on temporary workers or costly overtime, potentially compromising quality and escalating costs (Vavra, 2022). These risks emphasize the importance of proactive risk management to reduce the occurrence of global claims and ensure projects are delivered on time and within budget.

Contractual and Technical Risks

Technical risks in construction often arise from unclear contracts, ambiguous terms, and miscommunications, which can lead to confusion, disagreements, and construction errors. These issues may cause delays, cost overruns, and even legal disputes, particularly when contracts lack clarity about responsibilities for unexpected conditions or material quality (AEI Consultants, 2023). Such ambiguities can result in differing expectations, prompting contractors to file global claims to recover additional time and costs. Design errors and inadequate specifications also contribute significantly to technical risks by causing rework, increased labour and material expenses, and disruptions to project schedules. When projects rely on incorrect or incomplete specifications, substantial corrections may be necessary. To reduce these risks, it is essential to have clear, comprehensive contracts with consistent terminology and ensure that all parties understand the terms. Additionally, reviewing technical drawings and specifications before construction begins helps prevent miscommunication and supports smoother project execution (AEI Consultants, 2023).

Project Management Risk

Effective project management plays a vital role in reducing risks that lead to global claims in construction. Poor communication and collaboration often cause misunderstandings, errors, and project delays (Fahad & Musa Mohamad, 2023). Unclear communication channels can lead to conflicts over scope, timelines, and deliverables. Design errors, such as inconsistencies between architectural and engineering plans, may remain undetected until late stages, resulting in costly revisions and disputes over accountability (Keane & Caletka, 2015). Inadequate risk assessment during planning further increases the potential for global claims, as stakeholders are left to respond reactively to unforeseen issues (Ellis, 2023). Financial mismanagement, including budget discrepancies and payment disputes, also contributes to claims (Vavra, 2022). To mitigate these risks, project teams must prioritize clear communication, thorough planning, effective design coordination, and strong financial oversight, thereby promoting smoother execution and reducing the likelihood of disputes.

External Risk Factor

External risks in construction, such as weather changes, force majeure events, inflation, material cost fluctuations, and pandemics, can cause major delays and cost increases (Brock Andony, 2022). Supply chain disruptions may delay material deliveries, while inflation and raw material shortages can strain budgets. Contractors often face the choice of absorbing costs or renegotiating contracts, which can lead to disputes and project delays. To address these risks, contracts typically include provisions for unforeseen events or force majeure clauses (BoologaSundaraVijayan, 2023), though such measures cannot fully prevent unpredictability. As a result, global claims are commonly used by contractors to seek compensation for costs arising from uncontrollable external factors. Haidar (2011) notes that when it becomes difficult to isolate specific causes of delay, contractors often attribute the impacts to broader external conditions. The effectiveness of such claims depends heavily on contract terms, particularly clauses allocating risk and defining compensation for external events.

2.4 *Court cases related to global claims*

With Malaysia's growing construction industry, disputes have become more frequent. The Construction Industry Payment & Adjudication Act 2012 (CIPAA) was enacted on April 15, 2014, to address payment delays and non-payment issues (Asian International Arbitration Centre, 2017). Since then, over 1,400 adjudication cases have been recorded, peaking at 708 in 2017 (Asian International Arbitration Centre, n.d.). However, many cases have been challenged in higher courts, highlighting tensions between fast dispute resolution and fairness. This study examines CIPAA cases involving global or total cost claims, particularly related to extensions of time and payment disputes. While cases from various court levels have been collected, only background information and relevant risk factors will be considered. Court of Appeal and Federal Court decisions are excluded from the study's scope. Delays and cost overruns often lead to withheld payments, prompting contractors to seek CIPAA adjudication. Counterclaims for breach of contract due to delays are common, as seen in *Maju Holding Sdn. Bhd. vs Spring Energy Sdn. Bhd. (2020)*. Employer-caused delays, as in *RC Asia Engineering Sdn. Bhd. vs Lion Pacific Sdn. Bhd. (2021)*, further escalate global claims when payment disputes and supply chain disruptions arise. Contractual and technical risks, such as breaches of contract, liquidated damages, and execution errors, also contribute to global claims. Cases like *Pancaran Prima Sdn. Bhd. vs Iswarabena Sdn. Bhd. (2020)* and *Econpile (M) Sdn. Bhd. vs ASM Development (KL) Sdn. Bhd. (2024)* highlight these complexities. Effective project management, as shown in *PI Brilliant Berhad vs Islah Mega Sdn. Bhd. (2024)*, is crucial in mitigating disputes. Many CIPAA adjudication cases escalate to the High Court and, in some instances, the Court of Appeal or Federal Court, often to enforce or contest decisions. As disputes progress, additional legal challenges—such as judicial reviews and winding-up proceedings—can arise, increasing litigation costs. While CIPAA aims to provide swift dispute resolution, prolonged court proceedings sometimes undermine its effectiveness, leading to costly legal battles.

2.5 Problems Associated with Global Claims

Global claims in construction often stem from stakeholder disputes, where establishing cause-and-effect links is difficult (Haidar, 2011). A major issue is concurrent delays—when both employer and contractor contribute to setbacks (Keane & Caletka, 2015). Contractors seek time extensions and cost compensation, while clients impose liquidated damages. These conflicts often escalate into arbitration, adjudication, or litigation, increasing costs and delaying project completion (Steward & Lindsay, 2023; Kim, 2020). Disputes arise when contractors emphasize employer-caused delays while ignoring their own faults. Clients may challenge claims, especially those with large financial demands. Early intervention through clear communication, documentation, and cost controls helps prevent escalation. Detailed records strengthen cause-and-effect links, reducing legal disputes (Strutt, n.d.). A major challenge in global claims is linking causes to outcomes. Contractors may adjust claims or shift the burden of proof, complicating liability disputes (Strutt, n.d.). This is especially problematic with external delays like climate change or material shortages. Clients must critically assess claims, ensuring accountability for controllable factors. While global claims benefit contractors, clients must stay proactive in risk evaluation (Shaikh et al., 2020). The ambiguity of global claims is a concern, as contractors may use them to consolidate issues, influence negotiations, or shift blame. This lack of clarity leads to disputes, delays, and higher costs (Bakhary et al., 2014). Underbidding or downplaying risks—then concealing miscalculations in a global claim—can create mistrust, worsening project delays and financial impacts (FTI Consulting, 2023).

2.6 Role of Quantity Surveyor and Mitigation

Quantity Surveyors (QS) play a crucial role in managing risks and ensuring project success by identifying, analyzing, and mitigating potential issues, reducing global claims, financial losses, and disputes (CCRAdmin, 2024). As risk managers, QS adopt a proactive approach from project inception to completion to prevent escalation (Haidar, 2011). Effective risk management integrates traditional methods with modern tools like Procore, Aconex, BIM, and data analytics, enhancing risk identification and mitigation (Ellis, 2023). These technologies provide real-time data access, enabling informed decisions and early detection of delays and cost overruns (CCRAdmin, 2024). Beyond technology, QS foster communication and collaboration among stakeholders. Transparent communication and documented interactions prevent misunderstandings and support dispute resolution (Sikich, 2019). Regular updates and thorough documentation ensure smoother project execution, minimizing global claim risks. Additionally, QS oversee cost control, monitoring variables like design changes, unforeseen conditions, and market shifts. By integrating cost planning, contract oversight, and risk mitigation, they help maintain financial stability and prevent budget overruns (Team, 2023).

III. RESEARCH METHODOLOGY & ETHICS

3.1 Introduction

Research methodology is a systematic approach used by researchers to collect, analyze, and interpret data to achieve their research objectives (Sreekumar, 2023). This methodology encompasses the underlying philosophy of the research, the types of data collected, the methods used to gather the data, and the techniques employed to analyze and interpret the findings. There are three primary research methodologies: Qualitative Research, which focuses on understanding phenomena through non-numerical data; Quantitative Research, which uses numerical data and statistical techniques to identify patterns and trends; and Mixed Methods, which combines both qualitative and quantitative approaches to provide a more comprehensive analysis.

3.2 Research design

This study will adopt a mixed-methods approach, combining both qualitative and quantitative data to provide a comprehensive understanding of the research topic. The qualitative component will involve a thorough literature review, including case studies of court cases, using an exploratory research design to examine the causes, management, and resolution of global claims in construction projects. This approach will help identify key themes, patterns, and underlying factors related to global claims. The quantitative method on the other hand, will focus on data collection through a structured questionnaire with closed-ended questions. Using closed-ended questions ensures clarity, consistency, and ease of analysis. The goal of this approach is to explore correlations between real-world scenarios and the data gathered in the literature review, thereby offering a more complete understanding of the research topic.

3.3 Data collection

A qualitative approach will be adopted to explore the complexities of global claims through an extensive literature review, including books, journals, court cases, and reputable online sources. This enables a deeper understanding of contributing factors. Key texts on project management, global claims, risk management, and dispute resolution will form the theoretical foundation, supported by scholarly articles from databases such as Google Scholar and ScienceDirect. Relevant Malaysian court cases, particularly from the Malaysian Law Journal Unpublished (MLJU), will also be reviewed to analyze judicial perspectives on construction disputes. Complementing this, a

quantitative approach will involve a structured survey comprising closed-ended questions using multiple-choice formats, Likert scales, and rating systems. The questionnaire will be distributed online and via email to Quantity Surveyors and firms listed by the Board of Quantity Surveyors Malaysia. Data collection is expected to take three to four weeks.

3.4 Data analysis

Data analysis will involve thematic analysis of court case data and descriptive statistics for questionnaire responses. Thematic analysis will include coding case content to identify key issues, which will be grouped into four main themes: financial, contractual and technical, project management, and external risks. The codes and themes will be refined to ensure consistency and enable comparison across cases. This structured approach aims to uncover the causes of global claims and inform effective risk management and dispute resolution strategies in construction projects. Questionnaire responses will be analysed using descriptive statistics in Microsoft Excel, with percentages, mean scores, and response frequencies used to interpret key trends. Likert scale responses will be numerically coded to assess average agreement on risk factors, ensuring internal consistency in the analysis. The coding process will support efficient data summarisation, while the findings will be cross-compared with qualitative themes from court cases. This integration will help identify convergence and divergence, strengthening the overall interpretive validity of the study.

3.5 Ethical considerations

This research will adhere strictly to ethical standards to uphold academic integrity. All sources will be properly cited to ensure transparency and prevent plagiarism, with accurate attribution reinforcing the credibility of the work. Only publicly accessible data will be used, ensuring compliance with copyright laws and avoiding infringement of intellectual property rights. This ethical approach reflects a commitment to responsible research practices. By maintaining transparency in data collection, analysis, and presentation, the study ensures reliability and academic rigor. Adhering to these principles not only strengthens the validity of the research but also promotes integrity within the wider academic community.

Table 1.0 Summary of Research Framework

Rationale / Problem Statement	Research Question	Research Objective	Research Method	Data Analysis
Global claims lack clarity, leading to disputes.	What causes global claims?	To identify the key risk factors that contribute to the occurrence of global claims.	Systematic review – Court Cases Analysis and Questionnaire	Thematic analysis
Global claims cause delays, cost overruns, and inefficiencies.	What are their impacts?	Analyze impacts of global claim in overall performance	Quantitative Method – Questionnaire and Court Cases Analysis	Descriptive analysis
QS roles in risk control are often underused.	How can QS help prevent them?	To examine the role of QS in risk mitigation of global claims in minimizing disputes and preventing global claims.	Quantitative Method – Questionnaire	Combined thematic and descriptive analysis

CONCLUSION

This research will investigate the issue of global claims in the construction industry, focusing on the key risk factors contributing to their occurrence, their potential impact on project performance, and the role of Quantity Surveyors in mitigating these risks. Through a mixed-methods approach involving literature and case law analysis alongside quantitative data collection, the study aims to uncover how financial, contractual, technical, managerial, and external risks influence the emergence of global claims and how these claims may lead to disputes, delays, and cost overruns. The anticipated findings are expected to highlight the importance of proactive documentation, contractual clarity, and structured risk management in reducing the prevalence and impact of global claims. This research also seeks to emphasize the strategic role of Quantity Surveyors in improving claim governance and dispute resolution practices. As a future recommendation, the study proposes enhancing contractual provisions, formalizing risk management protocols, leveraging digital tools for real-time project tracking, and strengthening the professional capabilities of Quantity Surveyors through advanced training. These strategies aim to support a more transparent, efficient, and collaborative construction environment, ultimately contributing to improved project outcomes and reduced disputes.

ACKNOWLEDGEMENT

The author would like to express his gratitude to Energy, Geoscience, Infrastructure and Society Department of Heriot Watt University, Malaysia, especially the supervisor for funding this publication. Special thanks are extended to my supervisors for their invaluable guidance and to my family for their unwavering support throughout this research journey.

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PLANNING APPROVAL DELAYS ASSESSMENT IN AFFORDABLE HOUSING PROJECTS

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ABSTRACT

As Malaysia's population reaches approximately 34 million in 2023, the demand for housing continues to grow, particularly in urbanizing regions like Johor. However, many struggles to afford a house pushing government to develop a policy such as the National Housing Policy and State government's policy for affordable housing, ensuring equitable access for low- and middle-income groups. However, despite the urgency to build affordable housing provisions, there appears to be delays in the planning approval process, affecting project timelines and governance efficiency. Prolonged approval durations can lead to cost overruns, inefficiencies in resource allocation, also weakened developer's cash flow and confidence, ultimately impacting housing supply and urban development. Thus, efficient governance is essential to fulfilling affordable housing policy objectives. While previous studies have examined regulatory inefficiencies and procedural barriers, many adopt a one-sided approach, favoring either government agencies or developers. This leaves a gap in understanding how governance structures, administrative processes, and inter-agency coordination contribute to discrepancies in approval durations. To address this, this study will provide the expected and actual planning approval durations for affordable housing projects in Johor and identifies key governance factors influencing these discrepancies. A qualitative research approach will be employed, utilizing document analysis and semi-structured interviews with key stakeholders, including local authority town planners and private developers. By assessing the governance and efficiency of approval processes, stakeholder roles, and decision-making mechanisms, this research aims to provide insights into optimizing planning frameworks, enhancing regulatory transparency, and improving asset performance through affordable housing supply in the housing sector. The findings will be valuable for policymakers, urban planners, and developers, contributing to a more efficient, accountable, and performance-driven planning approval system. Ultimately, this study will contribute to strengthening governance mechanisms in affordable housing development, supporting Malaysia's broader goals of effective asset management and sustainable urban growth.

Keywords: Affordable Housing, Factors of Causing Delays, Planning Approval, Projects Delay

I. INTRODUCTION

A. Research Background

The increasing demand for housing due to urbanization and an ever-growing population is said to be met only by new developments (Arfanuzzaman & Dahiya, 2019). This is due to rapid urbanization especially in developing country like Malaysia. This trend is due to migration from sub-urban to urban areas, where people seek more prospective jobs and life (UN Habitat, 2020; World Bank, 2018). In Malaysia, the population is growing fast and currently recorded at 34 million in 2024 where majority are aiming to reside in urban areas, reflecting the basis for shelter as emphasized in Maslow's hierarchy of needs. Human survival comes from housing, which is a source of security and stability (Maslow, 1943). As such there is an increase in demand for housing, especially affordable housing. Hence, Malaysia, need to accommodate this increasing demand for sufficient housing (Department of Statistics Malaysia, 2023).

Malaysian government have outlined, various initiatives such as the National Housing Policy (*Dasar Perumahan Negara*) to solve housing affordability and quality issues (Ministry of Housing and Local Government, 2019).

These policies give priority to low-income groups and are meant to help everyone afford housing. Figure 1.0 shows the framework of the National Housing Policy. In monitoring the policy, the National Property Information Centre (NAPIC) is responsible for reporting ongoing and post ongoing infrastructure of projects that are being constructed and constructed through robust information platforms.



Figure 1.0 Dasar Pembangunan negara (retrieve from Dasar Pembangunan Negara 2018-2025)

Malaysia's housing policy framework is based on centralised structure, divided into three tiers: *Dasar Utama* (Main Policy), *Sub-Dasar* (Sub-Policies), and *Akta dan Peraturan* (Acts and Regulations) (Dasar Pembangunan Negara 2018-2025). The first tier is the National Housing Policy (*Dasar Perumahan Negara*), which ensures sustainable urbanization and housing availability for all income groups. The second tier, the Sub-Policies, *Dasar Perumahan Mampu Milik Negara* (DRMM) focusses on the affordable housing for B40 and M40 groups, while *Pembangunan Hartanah Swasta* emphasizes private sector involvement also known as the open-market segments.

In addition, the housing development in Malaysia also aligned with SDG Goal 11: Sustainable Cities and Communities, which is guided by the theme of is inspired by the inclusive and sustainable urban development goals (United Nations, 2015). Access to affordable housing is a central part of that goal. However, the effectiveness of such efforts is critically dependent on efficient planning and development procedures (Marzukhi et al., 2020).

B. Problem Statement

Housing development in Malaysia is complex, requiring approvals from multiple agencies, including local authorities and land offices (Marzukhi et al., 2020). While these regulations ensure safety and environmental standards, inefficiencies and overlapping duties prolong housing development timelines (Banaeianjahromi & Smolander, 2019). In addition, the procedures can lead to delays in housing development approval due to bureaucratic inefficiencies in the planning approval process (Zain et al., n.d), poor coordination of stakeholders (Banaeianjahromi & Smolander, 2019), noncompliance with regulatory requirements (Durdyev, 2020), and inadequate documentation submission (Flentje et al., 2014).

The Malaysia Housing Policy aims to provide affordable, adequate, and quality housing to enhance living standards. It focuses on affordability for low- and middle-income groups, inclusive urban development, and sustainability (Ministry of Housing and Local Government, 2024). The policy promotes Rent-to-Own schemes, green building practices, and streamlining approvals via the One Stop Centre (OSC), which targets approval timelines within 99 days. However, misalignment between OSC schedules and local authority timelines often causes delays (Marzukhi et al., 2020). Regulatory and planning approval challenges further hinder project completion (Zainon et al., 2017).

Population growth, the need for shelter (Maslow's theory) and Malaysia's drive to increase supply of housing are further illustrated by the importance of efficient planning procedures in enhancing economic viability and realizing cost effective affordable housing. Policy such as National Housing Policy and Sustainable Development Goal 11 indicates that Malaysia is serious in sustaining its urban development, but inefficiency in the approval process has a huge potential gap between policy and practical implementation. With rapid urbanization, timely and affordable housing delivery is crucial.

Despite government efforts, development delays remain high, exceeding the 99-day approval target (Ministry of Housing and Local Government, 2019; Marzukhi et al., 2020). These delays not only extend project timelines but also increase costs, raising final housing prices (Zainon et al., 2017). Prolonged delays further exacerbate housing

shortages and may lower the quality of life for low-income households. Addressing these challenges requires identifying delay factors and implementing strategies to fast-track planning approvals, ensuring timely affordable housing delivery for Malaysia's growing population. To address these bottlenecks and assist the delivery of affordably priced housing and sustainable development, it is vital to profile the duration of planning approvals (Marzukhi et al., 2020).

C. Research Objectives

Based on the issues, the following research objectives have been established:

1. To profile the duration of planned and actual planning approval for affordable housing development.
2. To determine the factors contributing to the discrepancies in planning approval duration for affordable housing projects.

II. LITERATURE REVIEW

A. National Housing Policy

The National Housing Policy in Malaysia is a comprehensive framework that places a strong emphasis on guaranteeing that every citizen has access to housing that is both of high quality and affordable. This strategy is essential for addressing several housing-related issues, including affordability, quality, and encouraging sustainable urban growth. Figure 2.0 shows the National Housing Policy's aims and objectives.



Figure 2.0 *Dasar Perumahan Negara* 2018-2025

B. Planning Approval Process in Malaysia

Housing development planning approval process in Malaysia is presented as a structured workflow to comply with legal, technical and planning requirements. The One Stop Centre (OSC) manages this process by coordinating applications and reviewing them across departments and streamlining decision-making. The tasks and timeline of the development can be divided into several phases and each phase has special tasks and timelines, so that each element of development may be tested thoroughly. An overview of the stages involved in the planning approval process is shown in figure 3.0 below.

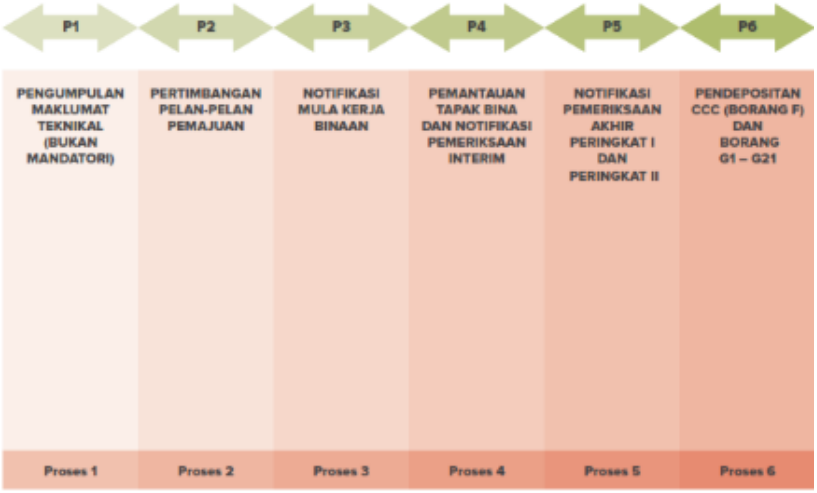


Figure 3.0 Overview Stages for Housing Development Process

From the general overview process, this study focuses on Stage 1 (P1) and Stage 2 (P2) of the process, which involve the collection of technical information and the consideration of development plans. These stages pertain specifically to planning approval rather than the subsequent construction phases. The flowchart focusing on planning approval in Stage 1 (P1) and Stage 2 (P2) is shown in figure 4.0 below.

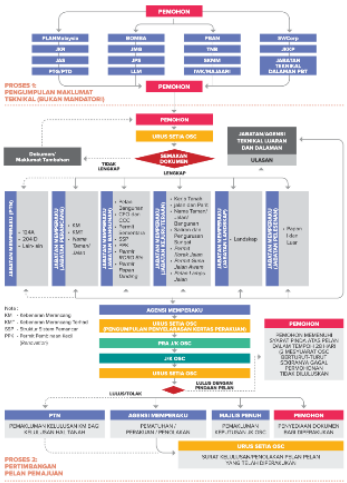


Figure 4.0 Flowchart for Planning Approval of Affordable Housing

C. Government Initiatives for Affordable Housing Development

The Malaysian government, through federal and state-level initiatives, has launched various programs to address housing affordability issues. The Malaysian government offers several affordable housing initiatives as shown in figure 5.0 below. The initiatives include:

a. Johor Affordable Housing Scheme (*Rumah Mampu Milik Johor*, RMMJ)
b. *Perumahan Rakyat 1Malaysia* (PR1MA)
c. *Program Perumahan Rakyat* (PPR)



Figure 5.0 Brochure of Affordable Housing Offered by Government

Malaysia's affordable housing programs cater to different income groups. In addition, the Johor government tailored their affordable housing policy suitable for Johor market. The Johor Affordable Housing Scheme (RMMJ) targets low- and middle-income Johor residents, offering homes ranging from RM42,000 to RM300,000 in high-demand areas. *Perumahan Rakyat 1Malaysia* (PR1MA) serves middle-income households (RM2,500–RM15,000), providing homes priced between RM100,000 and RM400,000 with financing options, although the program has faced delays. *Program Perumahan Rakyat* (PPR) supports the B40 group with rental units at RM124/month and ownership options from RM35,000 to RM42,000, ensuring affordable housing in urban and semi-urban areas (Perumahan et al., 2018). At least 40% of units are allocated to *Bumiputera* buyers, with a 7% discount. Additionally, Johor integrates green building concepts and public amenities to create sustainable and inclusive communities (Ministry of Housing and Local Government, 2024).

D. Affordable Housing Development

Urban development that provides equitable access to housing to low- and middle-income groups relies on the cornerstone of affordable housing. As a rapidly developing State in Malaysia, Johor has to strike a balance between providing affordable housing and urban expansion, given its strategic location next to Singapore and the Iskandar Malaysia development region (PKPJ, 2022).

E. Affordable Housing Demand

There is marked population growth in Johor, driven in part by rural-urban migration and the extension of its economic zones including Iskandar Malaysia. The demand for affordable housing is growing along with this, especially among low- and middle-income groups. In urban areas, escalating property prices driven by speculative investments and high-end property developments have made it hard for many to own homes (Zainon et al., 2017).

F. Overview of Recent Policy on Simultaneous Housing Development

The *Perbadanan Kemajuan Perumahan Johor* (PKPJ) policy mandates the simultaneous construction of open market and affordable housing units to promote inclusivity and balanced urban development. The PKPJ policy aims to address housing imbalances by requiring developers to allocate a portion of their projects to affordable housing, ensuring broader accessibility for low- and middle-income groups. This approach seeks to meet housing demand while balancing profitability with social responsibility. Additionally, the policy aligns with national housing agendas, supporting sustainable urban development goals. However, should there be any delay, it can increase costs, disrupt cash flow, and inefficiencies, which are exacerbated by the PKPJ policy's simultaneous construction requirement. A lack of clarity will further complicate project scheduling and financial management, contributing to inefficiencies in the housing development process (Assaf & Al-Hejji, 2006; Chan & Kumaraswamy, 1997). The simultaneous construction policy by PKPJ is shown in figure 6.0 below.



Figure 6.0 *Pendekatan Pembinaan Kediaman secara Serentak* (taken from *Polisi PKPJ* in Program "*Perumahan Johor: Apa Kata Anda?*", 2024)

G. Approval Duration Set by Government

The One-Stop Centre (OSC) sets approval timelines for housing projects: 99 days for medium-scale developments, 300-days for large-scale Type A projects, and 115 days for Type B projects (Marzukhi et al., 2020); Ministry of Housing and Local Government, 2024). However, Type A projects often face delays because they require approval from the National Physical Planning Council (NPFN) (*Portal Rasmi PLANMalaysia - Utama*, n.d.). The MPFN, chaired by the Prime Minister, meets only when necessary or at most once a year. This infrequent scheduling causes approval times in Johor to stretch from six months to over a year, exceeding the OSC's targets. These delays disrupt construction timelines, slow housing supply, and impact developers, policymakers, and homebuyers. Addressing these inefficiencies is crucial to meeting housing demand and ensuring timely project completion. Furthermore, some developers contribute to these delays by failing to comply with agency requirements before submitting plans to the OSC. Incomplete documentation or non-compliance extends approval timelines, increasing the risk of rejection or resubmission, further slowing progress.

H. Affordable Housing Quota

In Malaysia, including the states of Johor, regulations mandate developers to allocate a percentage of their projects to affordable housing based on the size of the land being developed (Hung, 2024). These quotas aim to ensure a balanced supply of affordable housing to meet the needs of low- and middle-income groups. In Johor, the specific guidelines required are shown as table 1 below.

Table 1.0 Reserve regulations for Affordable Housing set by *POLISI PERUMAHAN MAMPU MILIK JOHOR* (*Perpustakaan Negara Malaysia*)

Land Size for Development	Allocation for Affordable Housing
3 to 5 Acres	20% of Total Units
5 Acres and Above	40% of Total Units

The Johor government enforces these quotas to ensure that affordable housing remains a priority even as the state goes through tremendous economic and urban growth. These regulations demonstrate a commitment to ensuring quality housing developments in a sustainable, inclusive, and equitable fashion throughout the state.

I. Factor Contributing to Delay in Planning Development Permission

Several areas of research have identified factors contributing to delays in Planning Approval Affordable Housing. Table 2.0 below summarizes the factors listed in the research into both internal and external factors contributing to the discrepancies in planning approval duration for affordable housing projects.

Table 2.0 Summary of the factors contributing to the discrepancies in planning approval duration for affordable housing projects.

Category	Factors	Riazi et al., n.d	REHDA, 2021	Flentje et al., 2014	Banaeianjahromi & Smolander, 2019	Dlamini & Cumberlege, 2021	Durdyev, 2020	Md Zia Uddin, 2024
Internal	Bureaucratic inefficiency	✓	✓					
	Poor Coordination				✓			✓
External	Regulatory Changes					✓	✓	
	Inadequate Documentation			✓	✓			

III. RESEARCH METHODS

This study will employ a qualitative research approach to explore and profiling the planning approval durations for affordable housing projects. Qualitative methods emphasize understanding human behaviors and subjective experiences through non-numerical data such as interviews, observations, and text analysis (Earl, 2010). This

approach involves document analysis and semi-structured interviews to gain insights from key stakeholders in the approval process (Creswell & Clark, 2017). Hence, it is suitable to achieve RO1. To achieve this, document analysis will be conducted to compare the expected vs. actual planning approval durations using planning records and related documents. This helps identify discrepancies and contextual factors contributing to approval delays. As for RO2, semi-structured interviews with town planners and developers will be conducted to explore reasons behind these discrepancies. The sequential approach ensures that document analysis findings inform interview questions, leading to a systematic and in-depth investigation (Creswell, 2014; Kvale & Brinkmann, 2015). Through interviews, the study can capture detailed insights, focusing on general demographic questions before addressing the core study objectives (Ryan France et al., 2009).

To analyze the collected data, NVivo software will be used, which assists in organizing and coding textual data efficiently. The data will be examined using thematic analysis, allowing the researcher to identify, analyze, and report recurring themes and patterns within the interview transcripts and documents. This approach helps interpret the meaning behind participants' responses and supports the development of a clear understanding of the factors affecting planning approval durations.

This research will focus on Local Authorities in Zone A (*Majlis Bandaraya*), where six interviewees will be identified. The interviews will provide primary data for RO2 while contributing to RO1 through document collection and analysis. All interviewees will answer the same set of structured questions, divided into four sections as per the following Table 3.0.

Table 3.0 Semi-Structured Interview Questions Section

Section	Category of Information	Data Gathered
A	Interviewee Demographic	Interviewee Background in The Industry
B	Project Development Profile	Project Development Detail and Information
C	Profiling The Duration of Planning Approval	Expected and Actual Duration for The Planning Approval
D	Factors Contributing to Delay in Planning Approval	Factors contributing to delay from both sides of the interviewees' perspectives

Based on the research aim and nature, semi-structured interviews will be able to allow the researcher to gather more detailed information from participants based on their experiences, coupled with document analysis. Data will be analysed using content analysis by categorising and summarising the views of the interviewees.

IV. EXPECTED OUTCOMES

The expected research outcome will help shape the framework of this research. The expected comprehensive data collected from document analysis will provide a clear profile of the expected and actual planning approval durations for affordable housing developments in Johor, along with an overview of the project development planning process in the area. The document analysis will also offer insights into the approval process for projects of varying scales in Johor. The semi-structured interviews will provide an overview of the factors causing delays in the planning approval process for affordable housing developments in Johor from two different respondent perspectives. Unlike previous studies that categorized these factors into internal and external influences favouring one party, the semi-structured interviews will help align these factors, creating a more neutral perspective and identifying improvements to enhance the planning approval process.

CONCLUSIONS AND RECOMMENDATION

In conclusion, it is crucial for sustainable development while achieving and adhering to the government policies framework. This study will highlight the discrepancies in the planning approval durations for affordable housing in Johor and identifying the factor contributing to the delays in both parties' perspective which from both local authorities and developers. Unlike previous studies that often focused on one-sided views or generalized factor categorizations, this research adopts a more balanced and neutral approach by integrating insights from both parties. The findings will emphasize the need for streamlined approval improvements to prevent cost overruns, inefficiencies, and weakened developer confidence. Future research is encouraged to expand the scope of analysis to other regions in Malaysia and to include various categories of housing developments. By enhancing the

approval process, it will not only improve housing supply for people in need but also support the national development goals.

ACKNOWLEDGEMENT

The author wishes to thank to those who were involved and helped in facilitating this research process.

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ENHANCING BIM-BASED PROJECT EFFICIENCY THROUGH STANDARDIZED EXECUTION PLANS

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ABSTRACT

Building Information Modeling (BIM) has progressively become more popular over recent years, revolutionizing the methodologies applied in building project design, coordination, and construction. BIM is a revolutionary method that applies digital representation and real-time collaboration that has already been successful in enhancing productivity, minimizing project cost, and enhancing decision-making in project lifecycles. With these advantages, successful BIM implementation relies on well-documented systems and regulations like the BIM Execution Plan (BEP) to ensure all project stakeholders share the same outcomes. The lack of standardized for executing Building Execution Plans (BEP) is one of the primary hindrances. This research objective aims to identify the standard key element contents of BIM Execution Plan (BEP) for BIM-based projects. To accomplish that objective, ten BEPs are sourced worldwide, representing varied organizations were found and analysed using the technique of comparative analysis. Based on the results and findings on the ten templates, BEP is a strategic plan and monitoring document used to ensure all project deliverables are completed according to the project goals. The findings show that the KVMRT Malaysia (2016) template is the most efficient (81%) due to the clear-cut structure in project information, goals, and collaboration procedures. The CPI x UK (2013) template, however, shows the highest shortfall (43%) due to the lack of clarity in BIM process design, BIM information exchange and roles and responsibilities. The study underscores the necessity for BEP content standardization to enhance consistency and virtual collaboration in BIM-based projects, particularly within the Malaysian construction sector. The results present the most significant factors required for a standardised BEP and their role in improving project coordination and delivery performance. The proposed standardisation approach is designed to enhance efficiency, minimize confusion, and facilitate successful execution of BIM-based projects.

Keywords: Building Information Modeling (BIM), BIM Execution Plan (BEP), BIM documentation, Construction contract.

I. INTRODUCTION

Building Information Modeling (BIM) has been a significant component of the architecture, engineering, construction, and operations (AECO) sector, which facilitates enhanced decision-making at all phases of a construction project (Yang & Chou, 2018). As a result, several BIM documents have been developed in the sector to enable the cooperative processes and information management in a BIM project. These include norms, teamwork rules and project-level BIM execution plans (BEPs) (Building Smart, 2016). It is necessary to coordinate different project teams, since management and synchronization of big project data in the context of BIM can substantially minimize errors and rework but at the same time is still difficult (Galitskaya, 2019). Successful BIM implementation necessitates enhancing collaboration and communication during the construction process, which can be accomplished by utilizing the BIM Execution Planning Guide (BEP Guide).

II. PROBLEM STATEMENT

Although it is being used extensively, standardization of Building Information Modeling BIM execution plans (BEPs) remains inconsistent, resulting in inefficiencies and errors. Adoption of BIM by mainstream project management processes is resisted due to the perceived complexity and unwillingness to abandon and unwillingness to abandon conventional methods (Synek, 2018). Furthermore, while several guidelines and

templates exist, there is no comprehensive, standardized list of BEP elements that aligns with international information management frameworks such as ISO 19650 (Gadi, 2022). Many organizations experience inconsistencies in BEP content, structure, and methods, leading to inefficiencies and fragmented collaboration (Shawky, 2024). This research focuses on analysing different BEP templates to examine how they align with industry standards and best practices. These studies have brought attention to the need of standardising and adapting BEPs to various project types, contractual specifications, and construction stages. Thus, the standardization process can be employed to make it easier to integrate modern technologies and methods to boost the capabilities of building information modeling (BIM) (Cao & Huang, 2023).

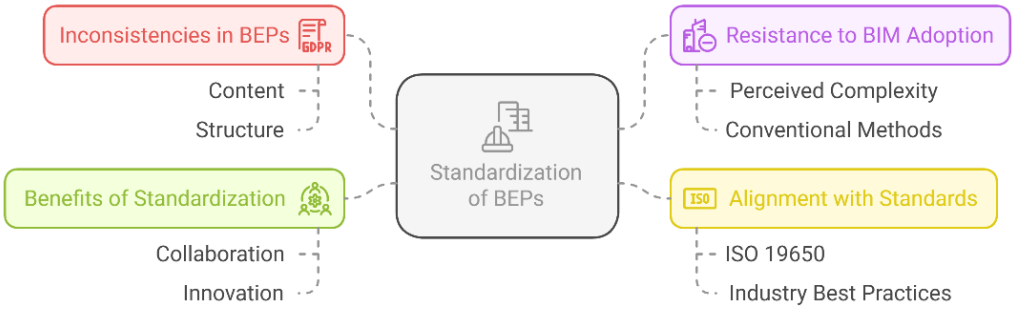


Figure 2: The need for Standardized Execution Plans

III. SIGNIFICANCE OF RESEARCH

Standardized BIM Execution Plans (BEPs) are increasingly recognized as essential for improving project efficiency and collaboration in the architecture, engineering, and construction (AEC) industry. BEPs provide a structured approach for defining project goals, roles, responsibilities, workflows, and information exchange, ensuring all stakeholders are aligned throughout the project lifecycle (Messner et al., 2025). Recent global reviews confirm that BEPs are instrumental in addressing challenges such as project fragmentation and poor information management, ultimately supporting better project outcomes and advancing digital transformation in the construction sector (Shawky, 2024; Abdelalim et al., 2024).

IV. LITERATURE REVIEW

A. BIM Execution Plan (BEP)

A BIM Execution Plan (BEP) is a planning document to aid in providing a standardized process and overall direction for strategic BIM adoption within a holistic strategy for a specific project or set of projects (Wu, W. & Issa, 2015). According to Galitskaya (2020), BEP contributes significantly to enhancing the coordination of various project teams by harmonizing project information in a BIM setting. This synchronization leads to minimized errors and rework, enhancing the project outcomes. Still, the construction industry continues to have challenges due to the absence of a standardized process for developing and implementing Building Energy Performance.

B. Key Elements Contents of BEP

A Building Information Modeling Execution Plan, or BEP, is a master document that outlines how a project is going to utilize Building Information Modeling (BIM) tools to deliver its goals. It puts all the stakeholders on a common understanding of deliverables, modeling standards, and data transfers. Initially, **Project Information** is an essential element of the BEP, laying the groundwork for the complete BIM execution. This segment details the project's scope, goals, and participants. Secondly, **Project Goals/BIM Objectives**. This section outlines the goals and objectives of implementing BIM in a project and explains how it helps achieve objectives at various phases. It emphasizes the necessity of having well-defined project objectives that correspond to the established of BIM applications in the BEP. Next, **Information Management** is a central focus in the BEP. This involves the administration, distribution, and preservation of data, guaranteeing that stakeholders can access the latest and most accurate information during every stage of the project. Bakar et al. (2021) emphasise the necessity of clear guidelines for data exchange and model sharing to mitigate errors and maintain consistency within the project team. Additionally, **Roles and Responsibilities** ensures accountability and effective job allocation by outlining

the roles and duties, timelines, and contact details of project team members (Charles Pankow Foundation, 2019). Effective problem solving is facilitated by clearly identifying boundaries of authority and working relationships. This framework proposes a detailed assignment of roles and responsibilities, ensuring all project participants know their duties and accountability. By clearly defining tasks, such a framework reduces the risk of miscommunication and overlapping responsibilities, which are common challenges in complex projects (Abdelalim et al., 2024). Furthermore, the BEP emphasises **software and tools** to verify that the platforms chosen are compatible throughout the project's lifecycle. Lin et al. (2016) state that selecting the appropriate tools and ensuring their compatibility is critical to avoiding integration issues that could stymie project development. This is further supported further by Kassem et al. (2014), who state that BIM's collaborative potential can only be fully realised when all parties involved are using the same tools and software.

In addition, BIM Process Design shows there are various phases in the BIM workflow, including pre-design, design, construction, and operation, laid down by Revizto (2025), where planning, design, and implementation of the project are enhanced by implementing BIM models by means such as scheduling and clash detection. ISO 19650 is interested in a Common Data Environment (CDE) in managing and distributing project data throughout the lifecycle, enabling coordination and making everyone who is invested in the project aware of accurate and up-to-date data. Moreover, Collaboration Procedures define how coordination and communication will take place between teams where it provides guidance on collaboration procedures within BIM Execution Plans (BEP), highlighting standard procedures for effective management and handover of information in a project. Then, there is Model Structure where it is link between object, building, campus, and state plane coordinate systems should be documented in the BEP, according to the Charles Pankow Foundation and BIM Forum (2019). A basic schematic that breaks down the model by zone, floor, building element, system, or discipline should be included in this part. The BIM Manager must also create standard naming standards for models. System conflicts can be avoided by using this naming convention, especially when moving drawings to archive systems such as the Smithsonian Institution's (Smithsonian Facilities, 2017). Besides that, Salaberri Martin (2022) highlights that ongoing model quality control involves the application of automated QA/QC processes to ensure BIM models possess specific requirements and standards, reducing errors and improving model quality. In model quality control, Revizto (2024) highlights the importance of ongoing audit and automation, like clash detection, to identify and resolve issues at an early stage of the project cycle, thereby improving overall model quality. Lastly, Project Deliverables specify about the outputs expected for BIM. This section contains a list of the project deliverables, their forms, and associated milestones, such as model submissions, conflict analysis reports, and the outcomes of coordination meetings, as stated by Charles Pankow Foundation (2019). Deliverables must adhere to the work program's timeline, and any delays should be resolved through risk management strategies. By accomplishing these objectives, the initiative will be consistent with the customer requirements of the BEP guidelines developed by Pennsylvania State University (2010). The overall transparency and communication among project teams are improved by an updated deliverables schedule, which offers clear guidance on project timelines and milestones.

C. The Importance of Standard Key Element Contents of BEP on Project Outcomes

Effective execution of BIM Execution Plans (BEPs) plays a crucial role in enhancing project outcomes by improving efficiency, coordination, and communication among stakeholders. BEPs provide a structured framework that helps projects stay on schedule and within budget by streamlining workflows, reducing uncertainties, and minimizing costly rework (Franz & Messner, 2019). Acting as a “rule book,” BEPs clearly define roles, responsibilities, and deliverables, which reduces misunderstandings and scope creep, ensuring all team members are aligned with project objectives (Franz & Messner, 2019). Furthermore, BEPs foster enhanced collaboration and information sharing, which is vital for interdisciplinary teams working on complex projects, thereby improving group cohesion and overall project performance (Siregar et al., 2024). The clarity and consistency provided by BEPs also facilitate smoother integration of data across different project phases, enabling stakeholders to work seamlessly and reducing delays caused by miscommunication (Siregar et al., 2024). Additionally, BEPs contribute significantly to transparency by enabling real-time access to accurate project data, which builds trust among stakeholders, supports informed decision-making, and promotes accountability throughout the project lifecycle (Olugboyega & Windapo, 2022). This transparency reduces conflicts and disputes, fostering a collaborative environment that is essential for successful project delivery. Moreover, the proactive planning and risk management encouraged by BEPs help identify potential issues early, allowing teams to mitigate risks before they impact cost or schedule (Franz & Messner, 2019). Collectively, these benefits demonstrate that effective BEP implementation is a key factor in realizing the full potential of BIM, driving improvements in productivity, quality, and stakeholder satisfaction in construction projects.

D. The Proposal Framework for Standardizing BEP Contents

In response to the increasing demand for standardized BIM Execution Plans (BEPs), recent studies have presented detailed frameworks intended to meet the diverse needs of construction projects. A framework suggested by Ab-declaim et al. (2024) identifies several key elements crucial to the standardization of BEP. This involves a precise definition of project objectives and details, making certain that all stakeholders have a common comprehension of the project scope. The framework highlights the importance and the need of assigning distinct roles and responsibilities to minimize miscommunication and duty overlap, as well as the establishment of collaboration processes that leverage centralized BIM databases for immediate coordination. Additionally, it incorporates information management and exchange protocols in accordance with ISO 19650 standards, facilitating a steady and clear data flow across the project lifecycle. To uphold quality and ensure compliance, the framework includes validation procedures and frequent model assessments. Its versatility across different project types and locations enables it to boost efficiency, minimize risks, and improve project results in the construction sector.

V. RESEARCH METHODOLOGY

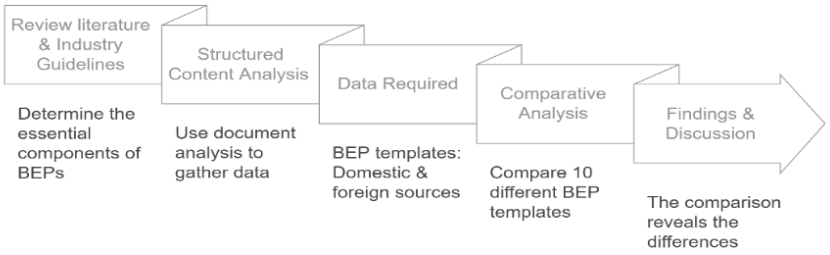


Figure 2: Research Design

This study used a structured content analysis approach to give a comprehensive knowledge of BIM Execution Plan (BEP) standardisation in the construction sector. This research is based on document analysis, with an emphasis on a systematic evaluation of ten (10) distinct BEP templates or guidelines. Specifically, this study will concentrate on BEP templates from both domestic and foreign sources to guarantee a thorough comprehension of BEP processes. The domestic templates examined include those from the Public Works Department (PWD) Malaysia (2014) and KVMRT Malaysia (2016), while the foreign templates include Penn State University (PSU), US (2010), NATSPEC Australia (2010), Building and Construction Authority (BCA), Singapore (2013), CPIx UK (2013), The Guide to Building Information Modelling, Belgium (2015), MBIE, New Zealand (2016), Port Authority of NY & NJ (2019), and Queensland, Brisbane (2019). By comparing the key element contents of templates, the study hopes to uncover best practices, similarities, and places for improvement. The analysis concentrated on ten primary elements which are project information, BIM goals/ objectives, roles and responsibilities, BIM process design, BIM information exchange, collaboration procedures, model structure, quality control, technology infrastructure, and project deliverables. Each template underwent a thorough review through a manual content checklist, capturing the presence or lack of specific elements in an Excel matrix. Previous studies often use words like “lack,” “insufficiency,” or “incomplete” to describe the absent in key element contents of BEP. For example, studies by Memon et al. (2014), and Ahmad et al. (2018) emphasize the lack of standardized frameworks and guidelines in BEPs. In this research, the words “efficiency” and deficiency” are employed instead. “Deficiency” specifically pertains to the lack or absent elements within BEP contents, while “efficiency” highlights the present of elements within BEP contents. The outcomes were subsequently transformed into percentage scores to evaluate content thoroughness and pinpoint shortcomings. Following the analysis of the data obtained, the study will move on to the final stage, which involves concluding and discussion of findings. At this stage, a conclusion will be drawn based on the ultimate findings and final output of this study.

VI. FINDINGS AND DISCUSSION

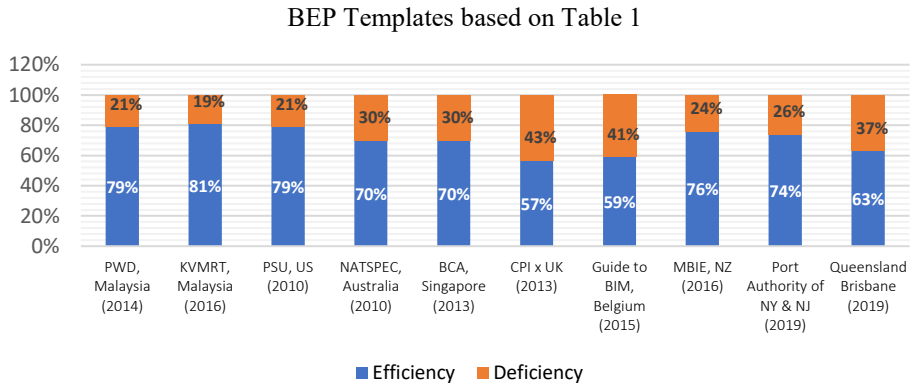


Figure 3: Bar chart of Percentage deficiency of key element content in BEP

Through a comprehensive examination of ten (10) BIM Execution Plans (BEPs), it was revealed that the organization and substance differ greatly based on the requirements of the project or organization. The bar chart above compares the efficiency and deficiency of various BIM Execution Plan (BEP) templates by various countries. Blue bars represent efficiency, and red bars represent lack or deficiency regarding key element contents in the BEP templates. Among these, the KVMRT Malaysia (2016) is notable for achieving the highest efficiency score of 81%, while both PWD Malaysia (2014) and Penn State University (PSU), USA (2010) follows closely with an efficiency score of 79%. These templates are very comprehensive in their contents and can be utilized as significant local references. The completeness of these documents gives clear directions to project teams, hence minimizing ambiguity throughout the project lifecycle. Their organized and comprehensive documents offer clear direction to project teams, diminishes uncertainty, and facilitates consistent collaboration throughout the project's duration. The roles of BIM Coordinator, Designer, and Project Manager improve accountability and help streamline project execution. Moreover, incorporating factors like model design and quality assurance enhances model precision, facilitates better communication, and promotes overall project achievement. MBIE New Zealand (2016) and Port Authority of NY & NJ (2019) showcased impressive efficiency rates of 76% and 74% respectively, establishing them as valuable international benchmarks that provide robust frameworks for BIM implementation

In contrast, the review points out significant deficiency in various other BEP templates. CPIx UK (2013) noted a significant lack at 43%, highlighting considerable deficiencies in essential aspects like BIM process design, information exchange, and role and responsibilities. The Guide to BIM (Belgium, 2015) indicated a deficiency of 41%, whereas Queensland Brisbane (2019) noted 37%. These templates are deficient in key aspects such as roles and responsibilities, BIM workflow organization, and technological infrastructure like hardware and software requirements. These gaps can lead to misunderstandings, poor coordination, and obstructed BIM implementation. Other than that, both NATSPEC Australia (2010) and BCA Singapore (2013) indicated a deficiency of 30%. Even though these BEPs provide crucial information, lacking depth and standardization in various fundamental aspects may result in inconsistencies, ineffective data management, and setbacks in project advancement

This comparison highlights the difference found in the creation of Building Execution Plan (BEP) templates in different regions. The analysis of BEP templates between different countries indicates that there are certain core elements, such as Project Information, present in at least eight BEPs. However, there are two of the BEPs do not complete this item in their templates, i.e., Queensland Brisbane (2019) and Guide to BIM, Belgium (2015). This suggests potential differences in the focus or priorities of BIM implementation for different regions. The difference in completeness could be due to the differences in the standards within each country or the change in project demands. Such differences are bound to hinder international coordination among regions or impinge on multi-disciplinary teamwork, hence reducing the effectiveness of BIM applications. There is a dire need for standardization of the contents of BEPs to achieve consistency, increase efficiency, and match the current BIM project demands. Standardized BEP frameworks would promote best practices, allow for effortless collaboration, and promote the adoption of BIM in the construction industry. Standardization would, in addition, increase the ability to benchmark the performance of projects and aid in the transformation towards digital and sustainable.

CONCLUSION

Standardized BEPs are instrumental in project efficiency by ensuring that all the stakeholders are on the same page and working collaboratively towards definite goals. The comparative analysis of the various BEP templates reveals significant differences in the completeness and coverage of important BIM elements. The findings emphasize the essential components required for the execution of BEPs. A precise description and contents of key elements enables all stakeholders to comprehend project objectives, workflow, task assigned, information required, and deliverable specifics. Based on the findings, Malaysian BEPs, KVMRT and PWD, have good coverage of content, and as a result, they are reliable local benchmarks to guide effective BIM implementation. On the other hand, less specific international BEPs such as CPIx UK and Belgium's guide show more deficiencies, which may be due to less focus on developing necessities such as technology infrastructure, BIM process design, and project deliverable. These differences illustrate the utmost importance of having a standardized BEP format in accordance with the latest industry demands and technological advancement. A detailed and structured BEP not only improves coordination and accountability but also the overall effectiveness of the project and reduces risks. Standardizing BEP contents across practices will allow stakeholders to have aligned expectations, better collaboration, and easier project delivery of BIM projects. Standardization of BEPs is ultimately required to improve BIM maturity and successful project delivery at both the local and international levels. By comparing various BEP templates, it was evident that some templates lack essential items, which may influence overall project performance. It is important to know what constitutes a good BEP and how these elements contribute to project delivery. Therefore, developing a more standardized and similar BEP format, particularly for BIM-based projects in Malaysia, will serve as the foundation for the next phase of this research.

GAP OF RESEARCH

This study relies solely on the document analysis of chosen BIM Execution Plan (BEP) templates. Although this method enables the recognition of standard key elements, it does not address for real-time execution or user feedback. Future studies might include interviews or case studies to achieve a better understanding of the practical uses and efficacy of standardized BEP materials

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APPENDIX

Table 1: The key elements contents in each BEP

ELEMENT	BEP Templates in Malaysia practice		BEP Templates from the overseas practice							
	Public Works Department (**PWD**), Malaysia (2014)	**KVMRT**, Malaysia (2016)	Penn State University (**PSU**), US (2010)	**NATSPEC** Australia (2010)	Building and Construction Authority (**BCA**), Singapore (2013)	CPI x UK (2013)	The Guide to Building Information Modelling, Belgium (2015)	MBIE, New Zealand (2016)	Port Authority of NY & NJ (2019)	Queensland Brisbane (2019)
a) Project Information										
Project Name	/	/	/	/	/	/	/	/	/	/
Project Scope Brief	/	/	/	/	/	/	X	/	/	/
Type of Contract	/	/	/	/	/	/	X	/	/	X
Project Schedule	/	/	/	/	/	/	X	/	/	/
Project Contacts	/	/	/	/	/	/	/	/	/	/
b) Project Goals/BIM Objectives										
Goal Description	/	/	/	/	/	/	/	/	/	/
BIM Uses	/	/	/	/	/	X	X	/	/	X
c) Roles and Responsibilities										
BIM / Model / Process Manager	/	/	/	/	/	X	/	/	/	/
BIM Lead Coordinator	/	X	X	/	X	X	X	/	/	X
BIM Coordinator	/	/	/	/	/	X	/	/	/	X
BIM Modeller / Author / Tech	/	/	X	X	/	/	/	X	/	/
BIM CAD / Support Group	/	/	X	/	X	X	/	X	/	X
Project / Construction Manager	/	/	/	/	/	/	/	/	/	/
Designers	/	/	/	/	/	/	/	/	/	/
Draught person	X	X	/	/	X	X	X	X	X	X
Quantity Surveyor / Cost Planner	/	X	X	/	/	X	/	/	X	/
Surveyor	X	X	X	X	/	X	X	/	X	X
Building Users / Owners / Client	X	/	/	/	/	X	/	/	/	X
Contractor	/	/	/	/	/	/	X	/	X	/
Subcontractor	X	X	X	/	/	X	X	X	X	/
Fabricator / Trade Contractor	X	X	/	/	X	X	X	X	X	/
Facility Manager	X	/	/	X	/	X	/	X	X	X
d) BIM Process Design										
Diagram / Process Map	/	/	/	X	X	X	/	X	X	X
Table	X	X	X	X	/	/	X	X	X	X
Paragraph	X	X	X	/	X	X	X	X	/	X
e) BIM Information Exchange										
Components to be modelled	/	/	/	/	/	X	/	/	/	/
Level of Detail	/	/	/	/	/	/	/	/	/	/
Level of Information	/	/	/	/	/	/	/	/	X	/
COBie	X	/	/	/	/	/	X	X	/	X
LOD Specification BIM Forum	X	X	X	X	X	X	/	/	X	X
Local/Own	/	/	X	X	X	X	X	X	/	/
f) Collaboration Procedures										
Collaboration Strategy / Plan	/	/	/	/	/	/	/	/	/	/
Model Coordination / Sharing	/	/	/	X	X	/	/	/	/	/
Meeting / Communication	/	/	/	/	X	X	X	/	/	/
Electronic Data Management	/	/	/	X	X	/	/	/	/	/
g) Model Structure										
File Naming Convention	/	/	/	X	/	/	/	/	/	/
Coordinate System	/	/	/	/	X	/	/	/	/	/
Model Structure Description	/	/	/	X	/	/	X	/	X	/
h) Model Quality Control										
Visual Check	/	/	/	X	/	X	/	/	/	/
Quality / Standard	/	/	/	X	/	/	/	/	/	/
Model / Data Integrity	/	/	/	X	X	/	/	/	/	/
Clash Detection / Interference	/	/	/	/	/	/	/	/	/	/
i) Technology Infrastructure Needs										
Software	/	/	/	/	/	/	/	/	/	/
Hardware	/	/	/	/	/	X	X	X	/	X
j) Project Deliverables										
Deliverables List	/	/	/	/	/	/	X	/	/	/
Milestone	/	/	/	/	X	/	X	/	/	X
PERCENTAGE EFFICIENCY	**79%**	**81%**	**79%**	**70%**	**70%**	**57%**	**59%**	**76%**	**74%**	**63%**
PERCENTAGE DEFICIENCY	**21%**	**19%**	**21%**	**30%**	**30%**	**43%**	**41%**	**24%**	**26%**	**37%**

THE IMPACT OF CONTRACTOR TERMINATION ON THE SABAH CONSTRUCTION INDUSTRY

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ABSTRACT

Construction industry plays a critical role as the key element of economic stability and sustainable development in Sabah. It provides basic infrastructure and creates wide job opportunities; however, the performance of the industry relies mainly on the contract between contractors and clients. Unfortunately, there is a staggering increase in cases of contractor termination in Sabah. Contractor termination will terminate the legal bond between the project owner and the contractor, indirectly cause projects to be abandoned or left incomplete. Several important infrastructure projects In Sabah have been delayed due to contractor termination, including the construction of Pan Borneo highway projects, and hospital developments in Beaufort. This research aims to address the issue by attaining the following objectives (1) Identifying the factors contributing to contractor termination, and (2) Identifying the implication of contractor termination on stakeholders in Sabah's construction projects. A qualitative approach will be employed for the research, involving two methods for each objective. Analysis of legal cases will be conducted to achieve the first objective. 10 relevant cases had been selected for the analysis through the LexisNexis database. The screening method involves keywords such as "termination, contractor, and Sabah", and the timeframe set from 2010 to 2024. Semi structured interview shall then be performed to achieve the second objective. Selected respondents include quantity surveyors with above 10 years of experience as project owners, consultants, and contractors. The interview responses shall then be transcribed for content analysis. The expected research outcome is the cultivation of useful insights on the factors and implication of contractor termination. The findings will assist project owners, policymakers, and construction professionals in implementing effective risk management strategies.

Keywords: Construction Industry, Contractor Termination, Sabah

I. INTRODUCTION

A. Research Background

The construction industry plays a crucial role as a driver of a country's economic growth (Boyce et al., 2018). A study by Alaloul et al. (2021) indicates that this sector serves as the backbone of the economy by providing the necessary infrastructure for social development, industrialization, and urbanization. Additionally, this sector also creates job opportunities, supporting a workforce ranging from unskilled to skilled labor, and stimulates economic activities in other sectors such as financial services, manufacturing, and trade (Boyce et al., 2018). Based on analysis and support from previous studies, the construction industry supports economic growth through the provision of basic infrastructure and job creation. Therefore, the significant role of the construction industry makes it essential to be given attention in the planning and implementation of national economic policies.

In Malaysia, the termination of construction contract has always been a serious issue and has its cost implications (Nor & Misnan, 2024). It refers to the act of ending the execution of rights and obligations agreed upon in a contractual relationship, thereby severing the legal ties between the project owner and the contractor in a construction contractual relationship (Truong & Ninh, 2017).

In Sabah, the issue of contractor termination is a major challenge that is frequently discussed. Many construction

projects, such as road construction, schools, and government buildings, have been affected due to contractors' failure to fulfill their responsibilities (Borneo Post, 2022). The Sabah government has taken strict action to terminate underperforming contractors, as stated by the Chief Minister, Datuk Seri Hajiji Noor, following delays in the construction of mosque in Ranau district (Fong, 2023).

B. Statement of Problems

Recent reports and analyses indicate that the issue of contractor termination in Malaysia's construction industry remains a critical challenge. For example, according to the Auditor-General's Report 2023, several major infrastructure projects in Malaysia, including those in Sabah, have experienced significant delays due to contractors' failure to fulfill their responsibilities, leading to the necessity of contract termination. This situation has resulted in increased project costs, more severe completion delays, and disruptions to planned public service infrastructure. Contract termination is not an unfamiliar issue in Sabah's construction industry. For instance, the Pan Borneo Highway project has faced significant delays, with several contractors having their contracts terminated immediately (MalaysiaKini, 2024). Issues related to land acquisition and changes in project implementation methods are among the factors contributing to these delays. As a result, road users have had to endure prolonged waiting times before the infrastructure could be made available for use. As a result of these delays and contractor terminations, the well-being of the people of Sabah has been affected, particularly those who rely on these projects to be completed promptly to meet their basic needs. Such projects are essential infrastructure that directly impact the quality of life of the local community.

C. Research Objectives

There are many factors leading to contractor termination. This issue also has indirect implications for the stakeholders involved in that particular project. Therefore, the following research objectives have been established to achieve comprehensive study results:

1. To identify the factors contributing to contractor termination in Sabah's construction projects.
2. To identify the implication of contractor termination on stakeholders in Sabah's construction projects.

II. LITERATURE REVIEW

Contract in Construction Industry

The Contracts Act 1950 defines a 'contract' as 'an agreement enforceable by law' (Section 2(h), Contract Act 1950). This definition emphasizes that the parties involved in a contract are bound by legal obligations. It also plays a crucial role in establishing a legally binding relationship between all parties involved. Generally, a contract often arises from differing interests that are aligned through negotiations and subsequently formalized in the form of a contract (Purwaningsih & Widyawati, 2023).

In the construction industry, project owners typically request bids from contractors based on a defined scope of work, including drawings, specifications, and contract conditions. Contractors then review these documents to assess performance risks and ensure that all potential conflicts are holistically addressed within the contract (Shash & Habash, 2020). From another perspective, a contract is a written agreement signed by the involved parties, binding them by defining their relationships and responsibilities in a specific project (Chong et al., 2011). The parties in a contract consist of various organizations, including owners, consultants, and contractors. They then collaborate under different delivery systems to execute various types of projects, such as commercial buildings, residential developments, industrial facilities, highways, dams, and more (Shash & Habash, 2020).

In the construction industry, several key elements must be fulfilled to ensure that a contract is valid and enforceable. The absence of these key elements in a contract will render the agreement invalid and unenforceable (Yusof, 2016).

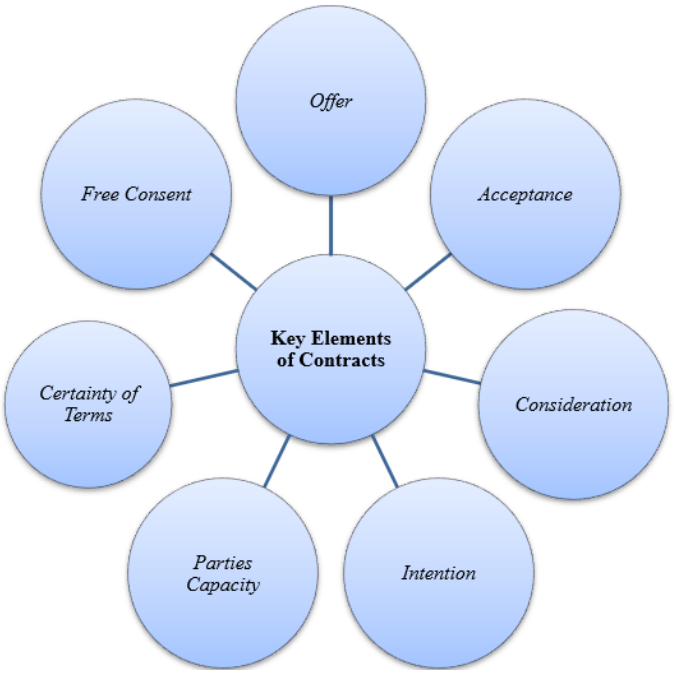


Figure 1.0 Key Elements of Conctracts

Section 2(a) of the Contracts Act 1950 states that an offer occurs when a person expresses their willingness to do or refrain from doing something with the intention of obtaining the other party's agreement. An offer must be clear, detailed, definite, precise, and complete to avoid any confusion (Yusof, 2016). Section 2(b) of the Contracts Act 1950 explains that acceptance in a contract is an unconditional agreement to the offer made. Section 10 of the Contracts Act 1950 stipulates that consideration in a contract must be lawful and not violate any legal provisions. For example, payment of money by an employer to a contractor for the execution of work is considered "consideration" in the context of a construction contract (Mohamed et al., 2011). Intention in a contract refers to the willingness of the parties to make their agreement legally binding (Yusof, 2016). This means that the contract is intentionally made to be legally valid and enforceable. It also states that only individuals with legal capacity, sound mind, and full contractual capability are eligible to enter a contract. This means that parties who do not meet the qualification criteria specified are not eligible to enter a contract. Section 30 of the Contracts Act 1950 states that an agreement that is vague or uncertain is invalid. This means that all parties involved in the contract must clearly understand their rights, responsibilities, and obligations as outlined in the contract document. Section 10(1) of the Contracts Act 1950 explicitly states that an agreement constitutes a contract if it is made freely between parties who are legally qualified to contract. Further elaborated in Section 14, a contract must be made without coercion, fraud, or undue influence. Section 13 defines free consent as a situation where two or more parties agree on the same matter with the same understanding.

Standard Form of Contract

In the construction industry in Malaysia, various types of standard contract forms are used to ensure systematic and organized project execution. However, the most commonly used standard contract forms in Malaysia are PWD 203A (Public Works Department), PAM 2018 (Pertubuhan Arkitek Malaysia), and IEM (Institution of Engineers, Malaysia) (Wen, 2024).

The PWD 203A form is one of the most widely used contract forms for government projects in Malaysia (Wen, 2024). It is an essential and commonly used contract in the public sector for projects between the Malaysian government and the parties involved in the project (Raja Berema et al., 2023). As a standard form in the public sector, it provides stability and efficiency in the management of government projects.

The PAM 2018 form is a standard contract form commonly used in private sector projects, particularly in the development industry. Upon review, this contract offers a detailed mechanism for managing variations and claims, ensuring flexibility in project execution. PAM 2018 is also suitable for various types of projects and includes specific clauses for managing interim payments, extension of time claims, and dispute resolution (Tay et al., 2020).

For civil and mechanical engineering projects, the standard contract form used is the IEM form (Institution of Engineers, Malaysia). This standard form focuses on technical specifications and safety, making it suitable for large infrastructure projects such as roads and bridges (Raojo, 2014). This means that the IEM standard form is appropriate for construction projects involving civil or mechanical engineering works, which typically require complex technical specifications and compliance with strict engineering standards.

Termination of Contractor in Construction Industry

Contract termination refers to the lawful termination of a contract before one of the parties has fulfilled their obligations (Trimble, 2021). According to common law, contract termination occurs when a valid and enforceable contract is ended either due to it becoming impossible to perform as a result of unforeseen circumstances at the time the contract was formed, or due to the actions of one party breaching the contract terms.

Factors Contributing to Contractor Termination

Under the Contracts Act 1950, non-compliance with the terms and conditions stated in the contract can be considered a legitimate breach of contract. For example, breaches such as a contractor's failure to complete the work within the agreed timeframe or not meeting technical specifications can be deemed serious violations. In the event of a material breach, the non-breaching party is released from any further obligations under the contract (Morris, 2024). Frustration has been defined as the forced termination of a contract due to the emergence of unforeseen circumstances and fundamental changes in the contract conditions (Maleki & Mohammadzadeh, 2017). Section 57 of the Contracts Act 1950 states that a contract becomes void when an event occurs that makes its performance impossible or illegal. For example, a contract becomes frustrated if a premise is destroyed by an accidental fire (Wilkins, 2022). Termination for convenience generally refers to the employer's authority to terminate the contractor's services without having to cite any failure or breach by the contractor (Lau, 2017). This means it is a right that grants the employer the freedom to terminate the contract for reasons that are not necessarily related to the contractor's performance but rather due to the employer's needs or interests. Recission of a contract can be subjected to Section 65 of the Contracts Act 1950. It provides that a contract can be voided due to a serious mistake or misunderstanding. The affected party has the right to cancel the contract and be restored to the position they would have been in had the contract not been completed. Corruption or illegal activities provision aims to ensure integrity and accountability in the execution of construction projects (Clause 53.0, PWD 203A). The government has the right to terminate the contract by issuing a written notice to the contractor if the contractor, its staff, or its workers are convicted by a court in relation to corruption or illegal activities.

Procedure for Contractor Termination

The procedure for contractor termination will be carried out according to the standard form of contract used in the project. There are slight differences in the termination terms between PWD 203A (Public Works Department) and PAM 2018 (Pertubuhan Arkitek Malaysia). However, it can be summarized as follows:

1. The contractor commits a breach of contract, and a breach notice is issued.
2. If the contractor fails to rectify the breach within fourteen (14) days after receiving the breach notice, the employer has the right, within ten (10) days after the expiration of the fourteen (14) days period, to issue an additional written notice (delivered by hand or registered mail) to terminate the contractor's services under the contract.
3. Following the termination, the contractor must vacate the site and hand over site possession to the employer.
4. The employer has the right to appoint another party to complete the work and rectify any defects.

Implication of Contractor Termination on Stakeholders

In the construction industry, contractor termination often has a significant impact on the project owner. If a contractor is terminated, the project owner must undergo the process of appointing a new contractor. This includes renegotiating the contract and conducting a new tender procurement process. This process not only takes a long time but also increases the overall project cost due to work delays. Additionally, compliance with contract termination laws must be emphasized and well understood, especially by project owners. This is to prevent illegal or non-compliant termination that does not adhere to the established contract laws. Failure to do so may give the original contractor the right to claim compensation from the project owner. As discussed by Aceris Law (2023),

disputes often arise due to misinterpretation of contract terms during the termination process. termination will prevent the contractor from continuing the execution of the project, which in turn will disrupt subcontractor work and ultimately affect the entire project supply chain. For example, subcontractors often experience delays in receiving payments when the main contractor has been terminated.

A study by Liew, (2019) found that subcontractors and suppliers are often exposed to high risks because they do not have a direct contractual relationship with the project owner. The MOJES Journal (2022) found that such disruptions can lead to financial losses for subcontractors and suppliers, especially if materials or labor have been planned and paid for in advance. In the long run, this issue can affect relationships between project stakeholders and reduce trust in the project management system in the future.

III. RESEARCH METHODOLOGY

A qualitative research approach, on the other hand, is applied in cases where the relationship between the collected data and observations is determined based on mathematical calculations (Khanday, 2023). This approach, which involves recording, analyzing, and exploring interrelated relationships within a subject, generates a large amount of raw data, whether obtained through statistical methods or other means (Dibekulu Bahir, 2020). Researchers typically rely on qualitative research design when they aim to draw conclusions about "why" a certain theory exists and "what" respondents express through that theory (Khanday, 2023). The author finds that the best and most suitable research design for this study is the qualitative approach. To ensure that the research is conducted effectively, the qualitative approach will be divided into two (2) methods.

Table 1.0 Breakdown of Qualitative Methods

Qualitative Approach	
Method	**Research Objectives**
Legal case analysis	To identify the factors contributing to contractor termination in Sabah's construction projects.
Semi-structured interviews	To identify the implication of contractor termination on stakeholders in Sabah's construction projects.

The qualitative research design approach using the legal case analysis method allows researchers to obtain empirical facts to support the study. It also helps in delivering the first research objective, which is to identify the factors contributing to contractor termination based on documentary evidence such as contracts and specific clauses found in published legal case reports.

For the second method, which is semi-structured interviews, it allows researchers to record detailed explanations of respondents' experiences and perspectives, providing a deeper understanding in delivering the second research objective, which is to identify the implications of contractor termination on stakeholders. It is also suitable for obtaining subjective and contextual data. Semi-structured interviews provide direct data that cannot be deeply obtained through document analysis alone.

IV. EXPECTED OUTCOMES

The research is expected to help shaping the framework for understanding contractor termination in the construction industry in Sabah. The identification of factors contributing to contractor termination will be highlighted based on legal case analysis and expert perspectives. Next, the implications of contractor termination on stakeholders, including project owners, contractors, and consultants, will be explored. This finding will be combined with possible strategies suggested by respondents to mitigate the negative effects of contractor termination and improve contract management practices in the industry.

IX. CONCLUSION

This research addresses the staggering issue of contractor termination in Sabah's construction industry. It outlines the need to explore contributing factors through legal case analysis and to understand stakeholder impacts based on expert insights, particularly from Quantity Surveyors who are experienced in handling project related to contractor termination. The study emphasizes the potential of these findings to inform better contractor assessment and improve risk management practices. However, the scope of this research is limited to Quantity Surveyors, which may not fully capture the perspectives of all construction stakeholders. Future research is recommended to include a broader range of participants such as project managers, engineers, and policymakers, to gain a more comprehensive understanding of the issue.

ACKNOWLEDGMENT

The main author would like to express his gratitude to Building Surveying Department of UiTM Perak branch, especially the supervisor for funding this publication. Special appreciation is extended to Dr. Zahierruden Ismail for his valuable supervision and guidance throughout the research process. The author also wishes to thank all the Quantity Surveyors who participated in the interview sessions for sharing their insights and professional experience.

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FACTORS AND MITIGATION STRATEGIES IN PLANNING AND SCHEDULING FOR DATA CENTRE CONSTRUCTION PROJECTS

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ABSTRACT

Data centre construction projects present significant challenges due to their technical requirements, rapid technological evolution. Poor planning and scheduling can result in delays, cost overruns, and operational inefficiencies. This research aims to achieve two main objectives: (1) to examine the key factors affecting the planning and scheduling processes in the construction of data centre building, and (2) to explore mitigation strategies used by industry practitioners to overcome challenges in planning and scheduling. The study aims to identify key factors affecting planning and scheduling in data centre construction projects and propose effective mitigation strategies. A case study approach was used, through semi-structured interviews. The research findings will contribute to the existing knowledge of construction project management, specifically in data centre projects.

Keywords: strategies, data centre, construction projects

I. INTRODUCTION

1.1 Research Background

In recent years, the remarkable pace of technological advancement has fundamentally reshaped how societies store, process, and exchange data. At the heart of this digital transformation lies the data centre, a critical infrastructure that supports everything from cloud computing and financial systems to AI-driven applications and real-time communications. As our dependence on digital services intensifies, so too does the need for more sophisticated, efficient, and scalable data centre facilities (Hernandez et al., 2023). The emergence of Artificial Intelligence (AI) has further elevated the strategic importance of data centre. No longer serving merely as data storage hubs, they now act as computational engines capable of handling complex tasks in healthcare, finance, manufacturing, and beyond. This evolution has brought about new technical demands, including the need for AI-compatible infrastructure, energy optimization, and responsive operational systems (Mishra, 2024)

Data centre is the technological innovation for the future. This is because with the advancement of optical networking and energy-efficient hardware, it has enabled the construction of more sustainable data centre and scalable (Saleh, 2013). The emergence of technologies in cooling systems, virtualization, and network efficiency have led to the growth of data centre (Zhang et al., 2018). The development of data centre as digital infrastructures has become a critical necessity due to the increased use of technology, digital services, and self- data protection driven by advancements of the Fourth Industrial Revolution (Hwaiyu Geng, 2021). Malaysia, in particular, has positioned itself as an emerging hub for data centre development within the Asia-Pacific region. Factors such as its access to renewable energy, availability of development-ready land, a maturing digital economy, and direct connectivity through submarine cable infrastructure have made the country increasingly attractive for global investors (PLANMalaysia, 2024). This trend highlights not only opportunities but also the responsibility to ensure that such complex projects are delivered efficiently and sustainably.

However, constructing data centre is far from straightforward. The construction for data centre involves integrating high tech systems such as cooling, power management, data security and network reliability. All of which demand precise planning and coordination (Rehman et al., 2020). Compounding this complexity are

persistent challenges such as resource shortages, labour constraints, and an often-inadequate adoption of modern construction tools like Building Information Modelling (BIM) (Zailani et al., 2016; Mukuka et al., 2016). When planning and scheduling are poorly executed, the result is not merely delay or budget overrun it can mean lost business continuity, compromised operational readiness, or diminished stakeholder trust. Addressing this issue requires more than traditional project management approaches. Instead, it calls for proactive risk management and the adoption of digital tools, such as predictive analytics, machine learning, and integrated BIM solutions, to support data-driven decision-making and improve schedule reliability (Viswanathan et al., 2020; Gurhun et al., 2022). For example, China National Petroleum Company Data centre successfully planned a large-scale enterprise data centre using comprehensive methodology based on project management (Luo, 2010).

Despite the increasing prominence of data centre construction globally, current academic literature still focuses predominantly on general construction challenges, offering limited insight into the specific issues associated with data centre projects. This gap underscores the need for targeted research that examines the planning and scheduling complexities unique to data centre. By doing so, the industry can better anticipate challenges, optimize project timelines, and deliver infrastructure that is both future-ready and operationally resilient.

1.2 Problem Statement

Planning and scheduling for data centre construction projects presents a unique set of challenges that extend beyond those typically encountered in general construction. Unlike conventional buildings, data centre requires the seamless integration of high-tech systems such as precision cooling, redundant power supply, and advanced networking infrastructure which increases the complexity of project coordination and timeline management (Rehman et al., 2020). These projects are further constrained by tight commissioning deadlines and the critical need for uninterrupted operations upon completion, making planning and scheduling an indispensable component of successful delivery.

Many construction projects face the issue when integrating BIM with conventional scheduling tools. While BIM has shown promise in enhancing project visualization and coordination, its limited synergy with scheduling tools often prevents planners from accounting for dynamic constraints such as permit approvals, adverse weather, funding uncertainties, and stakeholder dependencies (Hartmann et al., 2012). As a result, resource allocation and task sequencing suffer from inaccuracies that increase the risk of delays and rework. These limitations will hinder the accuracy of the resource planning and sequencing. Current schedules also always fail to leverage the historical project data predictive insights which resulting in redundant planning efforts and missed opportunities to improve efficiency (Wu & Soibelman, 2006).

Data centre are building that are energy-intensive and the construction projects often fails to incorporate the sustainable practices and energy-efficient solutions during the planning part (Khamees & Mleeh, 2020), (Bansal & Pal, 2011). The use of Artificial Intelligence (AI) when it comes to planning and scheduling is still limited because with many tools relying on the manual inputs and the old traditional methodologies. This gap prevents the adoption of advanced predictive and automated solutions (Liy et al., 2018). Data centre construction projects involve with complex interdependencies between task, resource, and timeline which traditional scheduling tools struggle to handle effectively.

Poor planning will always lead to project delays and suboptimal outcomes. Many failed projects often lacked detailed, customise plan, relying on superficial or copied strategies (Ayele, 2023). Insufficient or lack of planning and scheduling can result conflicts which could cause the increase cost and productivity losses. For example, in engineering projects, unresolved resource constraints often delay schedules and inflate costs (Greenwood & Gledson, 2012). Inadequate scheduling could lead to an unacceptable delay and operational inefficiency in which could result in business-critical failures (Akula, 2020). Moreover, poor coordination between job scheduling and data systems in data centre construction often reduces systems performance, impacting job completion times and increasing operational costs (Zhang et al., 2007).

To summarise, construction planning and scheduling have been widely studied in the general context, there remains a lack of targeted research focused on the specialised demands of data centre projects. This research seeks to address this gap by identifying the key factors that uniquely impact planning and scheduling in data centre construction and proposing context-specific mitigation strategies. The findings will contribute to improve the planning and scheduling processes which will ultimately ensuring the success in this critical factor.

1.3 Research Objectives

a) To examine the key factors affecting the planning and scheduling processes in the construction of data centre building.
b) To explore mitigation strategies used by industry practitioners to overcome challenges in planning and scheduling.

II. LITERATURE REVIEW

2.1 Overview of Data Centre Construction

Data centre is a dedicated space within a building which used to house computer systems and its component such as telecommunications and storage and storage systems. Data centre plays a vital role in the digital era. As we approach to the future, data centre represents the very core of our global connection. Countries such as Canada, France, Australis, the Netherlands, Russia, and Japan have built a ton of the data centre according to the data developed by Cloudscene (Faist, 2023). Data centre are essentials to support the industry nowadays such as finance, healthcare, and e-commerce. Following with the advancement Internet of Things (IoT) and Industry 4.0, manufacturers relying on big data analytics to enhance their operation. With the following exponential growth, the demand for data centre have significantly increased worldwide (Patel & Mishra, 2020).

Data centre is a building that require a high degree of technical precision. The facilities are designed carefully alongside the systems to ensure the operations uninterrupted. This can be included such as the HVAC systems, sustainability, power supplies and wireless sensor networks (Uptime Institute, 2022). Data centres have four classifications known as tiers. From Tier I, II, III and IV, offer from basic site infrastructure, redundant component site infrastructure, concurrently maintainable site infrastructure and fault tolerant site infrastructure (PLANMalaysia, 2024). Data centre that used the prefabricated components will enable faster deployment and scalability. Plus, the adaption of renewable energy and artificial intelligence, AI will improve the operational efficiency and reduced the environmental impact (Smith & Lee, 2020). It is necessary to understand the trends of data centre construction to address these challenges in this research.

2.2 The Importance of Data Centre

Data centre are vital infrastructures that play a crucial role in enabling individuals and communities to function and grow (Hwaiyu Geng, 2021). The surge in demand for services during the lockdown such as subscription-based streaming platforms like Netflix and Spotify, as well as communication tools like Zoom and Microsoft Teams has significantly increased average bandwidth usage per household and business (Hwaiyu Geng, 2021). This shift, alongside the growing reliance on cloud services and the monetization of data, has spurred changes in the industry, leading to more private equity and infrastructure fund investments and a rise in Merger and Acquisition (M&A) activity. As the global appetite for data, online content, digital communication, and entertainment continues to grow, the need for expanded data centre capacity becomes more critical.

Additionally, the advent of cellular network technologies like 5G has created a new type of network designed to connect virtually everyone and everything including machines, objects, and device (Hwaiyu Geng, 2021). This technology demands more bandwidth, faster speeds, and lower latency, requiring data centre infrastructure to be flexible and adaptable to meet these needs. With the growing need to bring computing power closer to the point of connectivity, edge data centres are becoming increasingly important. By processing data where it is generated, rather than sending it across multiple networks and data centres, response latency can be reduced, thus eliminating a bottleneck in the decision-making process (Hwaiyu Geng, 2021). In most cases, these edge data centres will be remotely managed and unstaffed, with machine learning enabling real-time adjustments to the infrastructure without requiring human intervention.

The growing significance of the data centre industry has led to various misconceptions, with one of the most common being exaggerated estimates of how much electricity data centres consume (Hwaiyu Geng, 2021). The most reliable global electricity use estimates for data centres come from a 2018 analysis published in *Science Magazine* in February 2020 (Masanet et al., 2020). According to this study, data centres accounted for about 0.9% of global electricity consumption in 2018, a decrease from 1.1% in 2010. Despite a sixfold increase in the number of computers, an elevenfold rise in data transfer, and a twenty-sixfold increase in total data storage capacity by 2018 compared to 2010, electricity use grew by only 6% (Jonathan Koomey, 2021). This remarkable stability in energy consumption was made possible by the adoption of best practices, as detailed in the *Data Center Handbook* 2nd edition. Even though data centres play a critical role in the global economy, their overall electricity consumption remains relatively low due to innovations that have dramatically improved their efficiency over time.

In summary, data centre construction is the cornerstone of modern buildings, because they are the bridge for digital transformation of industries and fostering technological advancement. Not only data centre enables the grow of community, but they also connect everyone virtually and consume way less electricity than we thought. Its strategic significance underscores the need for meticulous planning, innovative design, sustainable practices, and energy efficient in the development of these critical facilities.

2.3 Fundamental Principle of Data Centre Planning and Scheduling

Firstly, defining clear objectives is crucial to the planning and scheduling of data centre construction projects. Without specific and measurable goals, projects can face delays and inefficiencies (Ayele, 2023). Establishing objectives ensures alignment with business needs and provides direction for all activities in the project. Another principle is comprehensive scope definition**,** which involves clearly outlining the tasks, milestones, and deliverables of the project. If the scope is not well-defined, it could lead to scope creep and resource mismanagement, which can disrupt the project schedule (Harshavardhan et al., 2023). A detailed scope ensures that all project elements are properly planned and executed.

Additionally, prioritizing tasks is essential. For example, categorizing activities based on their criticality and dependencies helps to identify which tasks need immediate attention, reducing the risk of delays (Ballesteros-Pérez et al., 2018). This ensures that critical project milestones are achieved on time. Resource allocation and optimization is another key principle. If resources like labour and materials are not allocated efficiently, it can lead to bottlenecks and delays. Using optimization techniques can help ensure that resources are utilized effectively (Greenwood & Gledson, 2012). Furthermore, risk management integration is very important. For instance, if risks are not identified and mitigated early, it could result in unexpected delays or cost overruns (Safavi, 1990). Incorporating risk assessments into planning minimizes these disruptions. The use of advanced scheduling tools also plays a significant role. Tools like Primavera P6 or Microsoft Project allow for real-time monitoring and adjustments to schedules, ensuring projects stay on track (Harshavardhan et al., 2023). These tools are invaluable for managing complex projects like data centre construction.

In addition, time management and task sequencing are important principles. Poor sequencing of tasks can lead to delays, whereas tools like Gantt charts can help visualize and manage timelines effectively (Ballesteros-Pérez et al., 2018). Proper sequencing ensures smooth progress throughout the project. Moreover, stakeholder collaboration is vital. For instance, poor communication among project managers, engineers, and contractors can lead to misunderstandings that affect the schedule (Olson, 1982). A collaborative environment helps avoid such issues and ensures alignment among stakeholders. Adaptability and flexibility in planning are also necessary. For example, unforeseen changes like material shortages require adjustments to the schedule. Flexible planning methods help accommodate these changes without major disruptions (Cohen, 2023). Finally, monitoring and continuous **improvement** are critical. Regular progress tracking helps identify deviations early, and feedback loops allow for necessary adjustments to be made (Liu et al., 2018). This ensures that the project remains on track and improves over time.

2.4 Key Factors Affecting Planning and Scheduling of Data Centre Construction

There are many factors that could affecting the planning and scheduling of data centre construction. One of them is project too specific. Data centre construction is very complex. For instance, high tech system, critical timelines, and specialized needs (Bong, 2009). All of them need to be accurate to prevent any delay. Not only that, but critical path method (CPM) needs to be accurate too because if inefficient critical path analyses can lead to inaccuracies in schedule (Prabhahar & Ravichandran, 2011) The resource allocation of this project where limited availability of materials, labour, and equipment can be a huge factor in affecting the planning and scheduling of data centre construction projects (Harshvardhan et al., 2023)

Next, management-related can be an issue to the planning and scheduling of data centre construction project. If the project manager is lack of experience, this could lead too inefficient and delay to the project (Kog et al., 1999). Coordination and communication also important because for example poor collaboration among stakeholders could affect scheduling (Alaloul et al., 2020). Thus, a good communication is very important when it comes to planning and scheduling of construction of data centre project. Another factor that can affect planning and scheduling of data centre project is environmental and external factors. The weather conditions can be one of them because unpredictable weather condition can disrupt schedules, especially in large scale projects (Tokunaga et al.,

1984). Regulatory compliance is also another factor because any adherence to environmental and safety regulations can delay the project. (Nanchari, 2024)

Technological and data driven factors can be included. Poor integration of BIM into scheduling could impact the project timeline. (Hartmann et al., 2012). Lack of artificial intelligence and automation could hinder efficiency in scheduling (Liu et al., 2018). Poor analysis of historical scheduling could lead to delay too (Soibelman, 2006). Economic and resource factor could delay the planning of data entre construction projects. Budget constraints or insufficient funding could affect the resources availability and prioritization (AL-SODANI & Alajeeli, 2017). Cost optimization is also another reason why planning of data centre can be affected. This is because there are challenges in balancing ecological and economic factors (Kulejewski & Roston, 2023).

Next is the adoption of new technologies. Digital integration can affect the planning and scheduling of data centre project. The slow adoption of emerging technologies such as AI, machine learning, and BIM in planning and scheduling can be a huge factor too (Liu et al., 2018). The automation challenge which the resistance to or lack of automation in resource allocation and task sequencing can be another factor too (Chenet al., 2011). Lastly are physical and site conditions. The site-specific constraints are a factor like land is limited, soil conditions, or access issue where it could impact the timelines (Tounaga et al., 1984). The geographical location can be another reason too. Regional climate and regulations can influence the project pace (Nanchari, 2024). Data centre construction projects are influenced by the diverse factors such as organizational, environmental, financial, and technology domains. Understanding and mitigate these factors can significantly improve project timelines and outcomes.

III. RESEARCH METHODOLOGY

This is structured into five systematic stages to effectively address the stated objectives: (1) preliminary planning, (2) literature review, (3) data collection, (4) data analysis, and (5) conclusion and recommendations.

The first stage is to review and understanding the importance of data centre and the effect of ignoring a proper planning and scheduling. This way research topic was established. The objectives are driven from the problem statement. The second stage is the literature review. It is to increase and widen the research topic to facilitate comprehension of the research. The literature review is being undertaken to have a better understanding of the construction of the data centre project. The sources certify that the research is based on factual evidence and verifiable justifications. After that instrument data is established.

The third stage focuses on data collection. A qualitative research design is adopted, as it offers an in-depth understanding of complex, context-specific issues such as the planning and scheduling challenges in data centre construction. Given the exploratory nature of this study, semi-structured interviews are selected as the primary method for data collection. This approach allows for guided conversation while offering the flexibility to probe deeper into emerging themes based on respondents' expertise. The interviews will involve 5 - 8 industry professionals directly engaged in data centre projects. This is because many professionals are difficult to reach, and some companies decline interviews or unavailability of their staff for external engagements. The saturation point will be reach when the interviewee giving the same answer pattern from the interview question. Participants will be purposively selected based on their hands-on experience and professional involvement in planning and scheduling within the Malaysian data centre construction sector. Interviews will be conducted either online or face-to-face, depending on the availability and preference of the respondents. All of the respondents will ask for consent before being interview. Any official letter will be provided if it is being requested.

The fourth stages will be involved in data collection, analysis of data and findings. The data are analysed using thematic analysis to identify recurring themes and pattern related to challenges and strategies in planning and scheduling. Thematic coding will be carried out systematically, and themes will be developed both deductively (from the literature) and inductively (emerging from the data). Finally, the fifth stage involves drawing conclusions and developing practical recommendations based on the analysed data. These outcomes will directly inform industry practices and contribute to the academic discourse surrounding construction planning in high-tech infrastructure projects.

IV. EXPECTED OUTCOMES

This study is expected to uncover key themes related to planning and scheduling challenges in data centre construction, such as technological limitations (e.g., poor BIM integration), organisational coordination issues, external constraints (e.g., regulatory and environmental), and the underutilisation of AI and predictive tools. It will also identify practical mitigation strategies used by industry professionals, including adaptive scheduling techniques, collaborative planning models, and the integration of digital tools for real-time decision-making.

Practically, the study aims to support project managers, contractors, and policymakers with evidence-based strategies to improve planning efficiency, reduce delays, and strengthen delivery performance in the growing data centre sector.

CONCLUSIONS AND RECOMMENDATION

This study emphasises how crucial careful planning and scheduling are for ensuring the success of data centre construction projects. As these projects become more technologically advanced and complex, traditional ways of managing schedules often struggle to cope with unique demands. By exploring real-world industry insights, this research contributes new knowledge to the construction management field, particularly by highlighting context-specific factors and practical mitigation strategies that have been underrepresented in prior literature.

The findings aim to support contractors, planners, and project managers in making better-informed decisions in improving project delivery outcomes through informed planning decisions and the integration of advanced tools and methodologies. For any future research, more exploration on integration of artificial intelligence into scheduling systems to enhance predictive capabilities and comparative studies across different region on different types of data centra could be explored.

ACKNOWLEDGEMENT

The author wishes to thank those who helped in facilitating and assisting this research process.

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WORK PLANNING AND COSTS FOR WORK SAFETY AND HEALTH IN EARTH EXCAVATION AT CONSTRUCTION SITE

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ABSTRACT

Nowadays, excavation work at construction sites often faces serious safety issues and costs that lead to accidents where workers are buried in the ground and result in death. Other issues are such as the high cost of renting excavation equipment and paying machine operators. The objective of this study is to identify safety and health planning for excavation work and analyze the costs involved. The scope of the study focuses on high-risk construction sites where excavation work is carried out. Key personnel in excavation projects include safety and health officers, site safety supervisors, construction supervisors, and quantity surveyors. The study used qualitative methods by conducting interviews at high-risk construction sites and analyzing cost-related documents. The findings showed that excavation work requires careful planning by supervisors, safety officers, and project managers. Before excavation begins, the soil type must be identified, and protective barriers must be installed to prevent workers from falling. Proper cost management is also necessary for labor, training, equipment, and machinery. In conclusion, this study increases knowledge about excavation safety and cost management for workers and students. Excavation is a high-risk job that demands strict safety measures to prevent accidents. The study emphasizes the importance of proper planning to ensure worker safety and minimize risks on construction sites.

Keywords: Construction Sites, Work Planning, Safety and Health Cost, Earth Excavation, Risk

I. INTRODUCTION

A. Background of Research

Construction site risks are increasing, leading to worker injuries and deaths. Earth excavation work is especially dangerous as news reports highlight fatal accidents (Berita Harian Online, 5 November 2023). Excavations deeper than 1.5 meters pose higher risks, making safety precautions crucial (Zulkeflee et al., 2020). Unlike working at heights, excavation lacks specialized safety equipment (Dashan A/L Sengeny, 2022). However, safety measures like installing barriers are necessary. Proper procedures and cost management are essential to ensure worker safety in excavation work. Implementing these measures can help reduce accidents at construction sites (Jawadul Shamir et al., 2023).

B. Problem Statement

The construction industry is prone to accidents, particularly during excavation work, as highlighted by the tragic deaths of three Bangladeshi workers in Kelantan. This incident led the Kelantan Occupational Safety and Health Department (JKKP) to halt excavation activities at a project site in Kampung Maka, Labok. Employers are obligated under Section 15(1) of the Occupational Safety and Health Act 1994 to ensure safety and health at work, including construction sites (Berita Harian Online, 2023).

Accidents, such as falls from height, remain common on construction sites despite safety efforts. One example is the fatality of a worker who fell onto a drilling machine during excavation activities (Zulkeflee et al., 2020). This highlights the unpredictable nature of accidents, underscoring the need for comprehensive safety measures during

high-risk tasks like excavation.

In addition to safety concerns, managing construction resources is crucial for the contractor. Efficient financial management is necessary for renting machinery, paying workers' salaries, and purchasing building materials. The use of the "Critical Path Method" helps contractors monitor timelines and costs to optimize construction processes (Nurfarah Aishah Ismail et al., 2021).

High-risk excavation methods, like Horizontal Directional Drilling (HDD) for gas pipeline construction, introduce additional dangers. This method involves lifting, confined space work, and welding, necessitating thorough hazard identification and risk assessment to prevent accidents at the site (Dashan A/L Sengeny, 2022).

Lastly, without proper safety preparations for excavation work, project sites face significant risks, which can lead to closure. The importance of clear cost and safety procedures to minimize risks was emphasized by the President of the Sabah Builders Association (SBA) in the Borneo Post 2020, while emphasizing that safety protocols are essential for the success of any construction project (Jawadul Shamir Jamaluthin et al., 2023).

C. Research Objectives

Based on current issues, this research highlights safety requirements in earthworks on construction sites. Proper planning enhances safety and health while managing costs. Objectives focus on improving safety, controlling costs, and managing risks effectively in construction projects. To achieve the goals of this study, the research objectives are:

1. To identify safety and health planning for earth excavation work at construction sites.
2. To identify the costs required for compliance with safety and health aspects for excavation work at construction sites.

II. LITERATURE REVIEW

The literature review used in this research includes safety and health planning for earthmoving work and the costs required for earthmoving work at construction sites.

Construction Site

Basically, a construction site can consist of activities such as site preparation, excavation, structural works, installation and finishing (Egbuonu, 2018). This complex and ever-dynamic environment can be called a construction site. Construction projects come in various scales, with large and small projects differing greatly in terms of cost and time.

Excavation Work

The Department of Occupational Safety and Health (DOSH) has defined excavation as the removal of soil, rock or other materials associated with construction or demolition work. This excavation will use machinery to create an open surface. It also includes earthworks, holes, tunnels or underground work (Occupational Health and Safety, 2015).

Occupational Safety and Health

The definition of occupational safety and health focuses on protecting the safety, health and well-being of workers. Organizations must prioritize workplace safety. In Malaysia, employers are legally responsible under the Occupational Safety and Health (OSH) (Amendment) Act 2022 to ensure the safety of workers. The Department of Occupational Safety and Health, under the Ministry of Human Resources, oversees OSH regulations (Occupational Health and Safety, 2010).

Safety and Health Planning

Safety and health planning are essential to protect workers. Organizations play a key role in ensuring effective implementation. Safety representatives oversee planning through regulations and actions to reduce risks and prevent accidents. Proper planning helps maintain a safe and healthy work environment for all employees. (Ashira G., 2024).

Accident

An accident is an unexpected or dangerous event, sometimes caused by weaknesses in an organization's safety system (Cláudia Niza, 2008). So, individuals must stay cautious to prevent accidents and organizations should improve safety planning. Strengthening safety measures can help reduce workplace hazards and protect workers from potential risks.

Safety and Health Costs

Safety and health costs refer to the expenses incurred by employers to implement safety measures and reduce accidents in the workplace (Oscar, 2022). Under Section 15(2)(e) of the Occupational Safety and Health Act 1994, employers must ensure the safety of employees. This is because effective safety practices can reduce costs and demonstrate the employer's commitment to workplace safety.

Safety and Health Regulations for Earth Excavation Work

Safety and health regulations for earth excavation work are linked to the Factories and Machinery Act (FMA) 1967 and the Occupational Safety and Health (Amendment) Act 2022. The Factory and Machinery Act (FMA) is a law that regulates safety in factories and the use of machinery in Malaysia. The main purpose of this act is to regulate the use of machinery and ensure a safe workplace for workers. The Occupational Safety and Health (Amendment) Act 2022 aims to introduce changes to improve workplace safety and ensure compliance with the law in Malaysia (Abu Seman et al., 2024).

Parties Involved in the Implementation of Safety and Health in Excavation Work

According to the Department of Occupational Safety and Health (DOSH), there are several parties involved in the implementation of safety and health in excavation work. These include employers, self-employed people, clients, builders, professional engineers, project managers, Safety and Health Officers (SHOs), site safety supervisors and workers.

Elements of Safety and Health in Excavation Work

There are several elements of safety and health in excavation work that are required to overcome the associated risks. Each of these elements is important to ensure that all excavation work at a construction site runs smoothly by preventing accidents or unexpected events. Among the elements involved are the following.

1) Hazard Analysis

A hazard is a potential danger that can lead to accidents. Hazard analysis is part of risk management outlined in the Guidelines for Identification, Risk Assessment, and Risk Control (HIRARC). Every construction task including excavation work requires HIRARC to identify risks and ensure proper procedures, protecting workers and others in the area. (DOSH). The HIRARC form is shown in Figure 1.0.

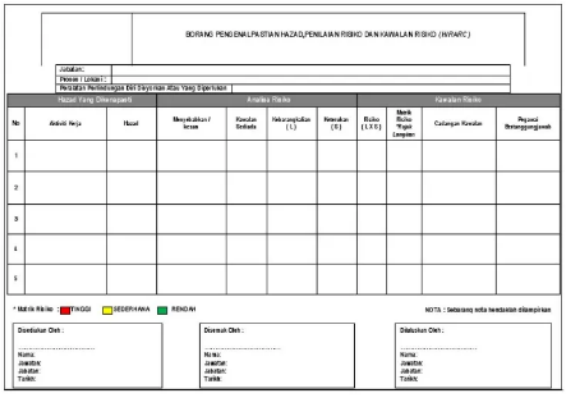


Figure 1.0 HIRARC Form

2) Emergency Response Plan

The Emergency Response Plan (ERP) aims to prepare an organization to be better prepared to face emergency cases. It helps the organization manage emergency situations or conditions in an orderly manner to reduce risks to humans and animals, environmental destruction and property damage. The emergency response plan prepared

by the Department of Occupational Safety and Health (DOSH).

3) Personal Protective Equipment (PPE)

Personal protective equipment (PPE) includes clothing and gear used to protect workers from workplace hazards (ROSH UKM, 2017). It is essential for safety and must be worn on-site. PPE helps reduce risks from minor hazards (Daeyoung Gil, 2024) and includes protection for the head, body, feet, hands, eyes, breathing, and hearing.

4) Obligations Workers in Carrying Out Excavation Work

The Department of Occupational Safety and Health (DOSH) provides safety guidelines for excavation work, while the Public Works Department (JKR) issues safe work instructions. Workers must follow these regulations to ensure excavation work is conducted safely and according to established standards.

Costs Involved in the Implementation of Safety and Health in Excavation Work.

Workplace safety and health are important in construction. Managers and workers must prioritize safety on site. To ensure safety, it requires costs for key elements including safety management, site safety and worker protection (Furqaan Nai'em, 2020). These costs help create a safe and healthy working environment.

1) Safety and Health Management Costs

Safety and health management involve workplace risk management. Organizations must invest in training and programs to educate employees on handling machinery, construction activities, and hazardous situations. These initiatives help improve workplace safety and require costs to ensure workers gain the necessary skills and knowledge (Oscar Rikhotso, 2022).

2) Construction Sites Safety Costs

Construction site safety depends on proper layout planning which requires specific safety costs. Contractors must allocate funds to meet safety requirements including managing materials, equipment, machinery, and hazardous areas. Essential safety measures include installing barriers, fences, and other protective structures to ensure a secure work environment (Xin Ning, 2013).

3) Worker Safety Costs

Worker safety costs cover expenses for protective equipment-like eye, body, foot, hand, respiratory, and hearing protection. Contractors must assess risks in hazardous areas to provide the right equipment (Yuntae Jeon et al., 2024). Since workers face many risks on-site, personal protective equipment is essential and must be available throughout the construction process to ensure their safety.

III. RESEARCH METHODOLOGY

Quantitative research focuses on numbers and measurements, while qualitative research explores understanding and context. This study uses qualitative methods, including interviews and document analysis from five excavation projects, to gather insights from professionals with different experiences. Interviews collect knowledge on safety and health planning, while document analysis identifies costs for safety compliance.

Table 1.0 outlines the study approach, respondents, required data, and analysis methods, providing a deeper understanding of excavation safety.

Table 1.0 Data Collection

Research Objective	Research Approach	Research Respondents	Data Analysis
Objective 1: To identify safety and health planning for earth excavation work at construction sites.	Qualitative: Semi-structured interviews with documents.	1. Safety and Health Officer (SHO) 2. Site Safety Supervisor (SSS) 3. Site Supervisor (SV) 4. Quantity Surveyor (QS)	Content analysis of data and information obtained.
Objective 2: To identify the costs required for compliance with safety and health aspects for earth excavation work at construction sites.	Qualitative: Document Analysis		

Based on Table 1.0, this research used a qualitative approach, including semi-structured interviews and document analysis, to ensure respondents had the right knowledge. Data was collected from five selected construction projects. Data was obtained from interviews with Safety and Health Officers, site safety supervisors and site supervisors. Cost data was obtained from the analysis of project documents.

IV. FINDINGS AND DISCUSSION

This study raises awareness of the risks in earth excavation at construction sites. It serves as a reference for

construction workers and students in managing safety and health. Additionally, it helps in planning safety and health costs to minimize accident risks during excavation work.
Table 2.0 shows the background of the project.

Table 2.0 Background of the project

Project No	Project Name	Project Type	Group Project	Respondents
Project 1	Council Home DBKL, Jalan Sungai Besi, Selangor	Excavation work to a depth of 2.5 meters for building piles	A	1. SHO 1 2. Site SV 1
Project 2	Pembangunan Bercampur Pasar Cheras & Council Homes, Jalan Seluang, Selangor	Excavation work to a depth of 2.8 meters for building piles		1. SSS 1 2. Site SV 2
Project 3	Elmina C9 Factory, U5 Shah Alam, Selangor	Excavation work to a depth of 2.6 meters for building piles	B	1. SSS 2 2. Site SV 3
Project 4	Realignment Works For 900mm Diameter Sewerage Pipe at Plot 9029, Precinct 14 Putrajaya	Excavation work to an 8 meter deep for sewer pipe installation		1. SHO 2 2. Site SV 4
Project 5	111 Menerung, Jalan Menerung, Bukit Bandaraya Bangsar, Kuala Lumpur	Excavation work to a depth of 25 meters for basement parking	C	1. SSS 3 2. Site SV 5

* Safety and Health Officer (SHO) – 2 respondents
* Site Safety Supervisor (SSS) – 3 respondents
* Site Supervisor (Site SV) – 5 respondents

Based on this Table 2.0, it shows the list of projects selected in this research. There are 5 different projects consisting of Project 1 is residential projects, Project 2 is market development, Project 3 is factories, Project 4 is sewer pipes and Project 5 is residential building with underground parking. This project is divided according to the purpose of data analysis, namely Project 1 and Project 2 in group A, Project 3 and Project 4 in group B and Project 5 is group C. Project 4 involves Indah Water as the responsible party because the excavation area is close to the company building. The excavation for projects 1, 2 and 3 is for the installation of pile caps on the building foundation while Project 4 is for the installation of sewer pipes. For Project 5, it excavates the ground to create an underground car park. The total depth of the excavation Project 5 is 25 meters compared to Project 1 which is 2.5 meters, Project 2 is 2.8 meters, Project 3 is 2.6 meters and Project 4 is 8 meters deep. This project was selected with different excavation depths to identify the planning and cost of safety and health excavation work for each project, whether it was different or still the same for different projects.

a. *Safety and health planning for earth excavation work at construction sites.*

Table 3.0 shows the data collection to identify safety and health planning for earth excavation work at construction sites for five projects.

Table 3.0 Safety and health planning for earth excavation work at construction sites

Contents	Project 1	Project 2	Project 3	Project 4	Project 5
1) Hazards that often occur during excavation work at construction sites					
Type of hazard	Physical	Physical	Physical and electrical	Physical and chemical	Physical
Action taken/ Hierarchy of control	Prepare basic PPE, permit to work, signage, GI Pipe, HIRARC, method statement, and stop work (if have incident).	Permit to work, tools box meeting, basic PPE, prepare barricade (GI pipe), signage, and use whistle (if emergency).	Method slope shoring (1:2), tools box meeting, signage, and plastic barricade.	Use sheet pile, signage, tools box meeting, use exhaust fan and blower, PPE include mask and goggles, access in out, permit to work, HIRARC and procedure.	Use canvas barricade, signage, double check drawing and authority, access for confinement space.
Parties involved	Experienced worker, SHO, SSS, Site SV (guide work).	Planner, SHO, Site SV, Operator, Engineer and experienced work.	SSS, Site SV, experienced worker, and operator.	SHO, Site SV, general worker (experienced).	Skill worker, SSS, Site SV and general worker.
2) Emergency Response Plan (ERP) used for excavation work at construction sites					
Way to handle	Identify issues, use first aid, inform responsible parties.	Worker training, briefing, use	Use first aid (mild case), workers inform safety, and	Establish ERP by dividing the task based on party	Assembly points, count head, report

emergency action plans		emergency exits (if have incident).	safety send the victim to the hospital or call KKM (heavy case).	involve, safety monitor and arranging training.	and inform authority.
Machine maintenance	1 time/ 3 months (depending on type of machine)	1 time/ month (inspection weakness sticker by SHO/SSS)	1 time/ month (periodic have record and foreman take over)	1 time/ month	1 time/ month
Emergency drills	2 times/ 6 months (Random day and just inform early)	2 times/ 6 months (Assembly point or entrance)	2 times/ 6 months (Assembly point at outside area)	1 time/year	1 time/year
Tools box meeting	1 time/week	1 time/week	1 time/week	1 time/week	1 time/week
Responsible parties	Project director, Project Manager, SHO, Team workers, KKM, TNB, SYABAS, TM.	KKM, PDRM, JBPM, JKKP, DBKL, JPAM	Every party at the site involves Sime Darby (client).	SHO, Site SV, Project Manager, Indah Water, KKM.	JKKP, KKM, CIDB, and PBT (DBKL)

* Angkatan Pertahanan Awam Malaysia (JPAM)
* Construction Industry Development Board (CIDB)
* Dewan Bandaraya Kuala Lumpur (DBKL)
* Galvanized Iron Pipe (GI Pipe)
* Hazard Identification, Risk Assessment, and Risk Control (HIRARC)
* Kementerian Kesihatan Malaysia (KKM)
* Pihak Berkuasa Tempatan (PBT)
* Polis Diraja Malaysia (PDRM)
* Safety and Health Officer (SHO)
* Site Safety Supervisor (Site Safety)
* Site Supervisor (Site SV)
* Syarikat Bekalan Air Selangor (SYABAS)
* Telekom Malaysia (TM)
* Tenaga Nasional Berhad (TNB)
* Jabatan Bomba dan Penyelamat Malaysia (JBPM)
* Jabatan Keselamatan dan Kesihatan Pekerjaan (JKKP)

Based on Table 3.0, it shows the safety and health planning for earth excavation works at construction sites varies by project type, soil, and hazards. Group A consists of Projects 1 and 2 including residential and market development projects with similar physical hazards but different hazard management and responsible parties. Group B consists of Project 3 about factory and Project 4 related sewer pipe installation projects with physical, electrical, and chemical hazards, while Group C involves a basement parking project with physical hazards. Emergency training frequency also differs across projects. Safety planning includes soil monitoring, hazard identification, and site-specific measures like ground covers or barriers to prevent accidents. Safety equipment usage is consistent, except for pipe welding projects that require additional protective gear.

Through the data obtained, it is shown that the safety and health planning for earth excavation work at construction sites depends on project type, soil conditions, and hazards. It includes monitoring soil types, hazard identification, emergency handling, and periodic checks. For sloped excavation, ground covers like canvas or plastic are used, while for level land, GI pipes or steel bars are placed as barriers to prevent soil collapse. Personal protective equipment is standard for most projects and additional protective gear such as masks and goggles required for pipe welding work. Overall, the planning ensures compliance with safety standards particularly in excavation tasks to prevent accidents at the site.

b. *Costs required for compliance with safety and health aspects of earthmoving work at construction sites.* Table 4.0 shows the data collection to identify the costs required for compliance with safety and health aspects for earthmoving work at construction sites for five projects.

Table 4.0 Costs required for compliance with safety and health aspects of earthmoving work at construction

Contents	**Project 1 (RM129,540,470)**	**Project 2 (RM200M)**	**Project 3 (RM96M)**	**Project 4 (RM2,398,750)**	**Project 5 (RM117,300,000)**	**Total Cost**
Employee Costs	RM15,000 **(25.08%)**	RM14,000 **(23.42%)**	RM8,900 **(14.89%)**	RM10,800 **(18.06%)**	RM11,090 **(18.55%)**	**RM59,790**
Cost of Machinery and Equipment	RM39,000 **(25.25%)**	RM43,400 **(27.64%)**	RM31,800 **(20.25%)**	RM8,550 **(5.45%)**	RM33,462 **(21.31%)**	**RM156,212**
Overhead Costs	RM100,000 **(24.28%)**	RM125,000 **(30.60%)**	RM73,360 **(17.96%)**	RM16,250 **(3.98%)**	RM93,825 **(22.97%)**	**RM408,435**

* Ringgit Malaysia (RM)
* Millions (M)

Based on Table 4.0, it shows that the costs for the five construction projects differ significantly, ranging from RM2.4 million to RM200 million. The data was analysed by calculating the total costs for labour, machinery and overhead to obtain percentages that facilitate the understanding of the research data. The total cost is obtained by adding up each cost of employee, machinery and equipment, and overhead. The percentage for each item is calculated using the formula, item cost divided by total cost and multiplied by one hundred percent. Employee costs include salaries for Safety and Health Officers (SHO) or site safety supervisors, construction site supervisors and construction site workers. Machinery and equipment costs include the cost of renting or maintaining machinery and purchasing safety equipment such as personal protective equipment (PPE) and barriers for excavation work. While overhead costs include costs for preliminary, inspection and indirect costs. Group A shows that Project 1 has higher labour and machinery costs than Project 2, while Project 2 incurs more overhead costs due to design and worker training. Group B, consisting of Projects 3 and 4, has higher costs for Project 3 (RM96 million) compared to Project 4 (RM2.4 million). Group C, Project 5 has its own machinery which affects the cost of equipment.

Based on the data analysis, adequate costs for earth excavation work are essential to ensure worker safety on construction sites. These costs cover workers' wages, safety equipment, and training for excavation work. Costs vary depending on the number of workers, such as higher wages for Safety and Health Officers (SHO) compared to site safety supervisors. Sufficient funds for safety equipment and training are necessary to maintain safety without affecting the project budget. Overall, these costs are crucial for planning safety and health during excavation work at construction sites.

CONCLUSION

In conclusion, ensuring safety and health on earth excavation works is important because of the high risk of accidents. In addition, construction site managers must allocate sufficient costs for proper safety and health management so that the project is not affected by work delays from accidents that occur. Furthermore, since this study only focused on earth excavation works, future research should explore other high-risk construction activities. This will provide valuable references for managing safe construction projects effectively.

ACKNOWLEDGMENT

The author would like to thank the UTM Faculty of Built Environment and Surveying, supervisors and all parties who assisted in various aspects of the research process.

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THE INTEGRATION OF UNMANNED AERIAL VEHICLES (UAVS) IN MALAYSIA CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry is increasingly adopting Unmanned Aerial Vehicles (UAVs) to enhance efficiency, safety, and accuracy in various project phases. This conceptual paper examines the integration of UAVs within the construction sector, focusing on their applications, benefits, and challenges. Grounded in the theoretical frameworks of technological innovation and diffusion of innovations theory, the paper explores how UAVs facilitate tasks such as site surveying, progress monitoring, and safety inspections. Key arguments highlight the potential of UAVs to reduce labor costs, improve data accuracy, and enhance safety by minimizing human exposure to hazardous environments. However, the paper also addresses significant challenges, including regulatory hurdles, privacy concerns, and the need for specialized training. By synthesizing insights from recent scholarly research, this paper underscores the transformative impact of UAVs on construction practices and provides recommendations for industry stakeholders to optimize UAV integration. The findings suggest that while UAVs offer substantial benefits, their successful implementation requires addressing technical, legal, and ethical considerations.

Keywords: Construction Industry, Privacy Concerns, Regulatory Challenges, Technological Innovation, Safety Inspections, Unmanned Aerial Vehicles,

I. INTRODUCTION

The construction industry in Malaysia, like many others worldwide, is experiencing a paradigm shift through the adoption of cutting-edge technologies to improve productivity, safety, and efficiency. Among the most promising innovations is the integration of Unmanned Aerial Vehicles (UAVs), commonly known as drones. These devices are increasingly employed for a range of functions including site surveying, progress monitoring, structural inspections, and aerial mapping. The Malaysian construction sector, faced with rising costs, labor shortages, and growing demand for rapid project delivery, is beginning to embrace UAV technology as a solution to these persistent challenges.

However, despite their growing global adoption, the integration of UAVs in Malaysia's construction sector remains in its infancy. Industry players face various challenges such as limited awareness, high initial investment costs, regulatory ambiguity, and concerns related to privacy and safety. Furthermore, there is a lack of comprehensive policies and frameworks guiding UAV use in construction, which hinders broader implementation across the industry. These barriers have led to uneven uptake and underutilization of UAV capabilities in local construction practices, thereby limiting their potential impact on project outcomes.

The problem this study seeks to address is the fragmented and underdeveloped integration of UAVs within Malaysia's construction industry. While some large-scale projects have successfully implemented drone-based solutions, small to medium enterprises (SMEs) lag behind due to constraints in expertise, capital, and regulatory understanding. This disparity not only affects project delivery but also Malaysia's broader ambitions to modernize its construction practices in line with Industrial Revolution 4.0 (IR4.0) goals.

The objectives of this research are threefold. First, it aims to investigate the current state of UAV integration in the Malaysian construction sector. Second, it seeks to identify the key benefits, limitations, and risks associated

with UAV deployment. Third, the study intends to propose a strategic framework that addresses regulatory, operational, and technical aspects to facilitate more widespread and effective adoption. By doing so, this research contributes to the growing body of knowledge on construction technology adoption in developing countries and supports policymakers and industry leaders in crafting informed strategies for digital transformation.

II. LITERATURE REVIEW

The application of Unmanned Aerial Vehicles (UAVs) in the construction industry has gained global momentum due to their potential to enhance efficiency, accuracy, and safety in various project phases. This literature review explores the current academic discourse on UAV integration in construction, with a particular focus on its relevance to the Malaysian context. Key themes include technological capabilities, benefits and limitations, regulatory considerations, and readiness for adoption.

Table 1.0 literature review summary

No	Focus of Study	Key Findings	Identified Gaps	Citation
1	Use of UAVs in construction tasks	UAVs enhance site surveys, monitoring, and safety; improve communication and documentation	Lack of local Malaysian context	Irizarry & Costa, 2016
2	UAVs for safety and hazard identification	UAVs reduce manual inspection risks and support safety management	Technical integration with BIM/GIS tools underdeveloped	Siebert & Teizer, 2014
3	Barriers to UAV adoption in developing countries	High cost and limited skilled operators hinder adoption, especially among SMEs	Insufficient training and digital infrastructure in Malaysia	Shakantu & Emuze, 2020
4	Digital technology challenges in Malaysia's construction sector	Poor digital readiness and lack of collaboration between academia and industry	Weak policy support and awareness in local construction firms	Abidin et al., 2019
5	Regulatory issues for drones in Malaysia	Complex approval processes and unclear drone regulations discourage construction sector adoption	Need for sector-specific UAV policy framework	Nopiah et al., 2021
6	Ethical and privacy issues with drone use	Raises concerns on data privacy, especially in urban zones with dense populations	No standard ethical or data-use guidelines in Malaysia	Marconi & Rango, 2019

The reviewed literature underscores that while UAVs offer promising benefits for the construction industry, their integration is hindered by regulatory ambiguity, cost barriers, and insufficient local expertise. The Malaysian construction industry is poised to benefit from UAV technology, but a strategic framework is essential to overcome current limitations. This research aims to contribute to the evolving body of knowledge by providing a context-specific analysis of UAV integration and proposing actionable solutions for stakeholders.

III. METHODOLOGY

This study adopts a conceptual research approach, aiming to explore and synthesize theoretical and empirical insights on the integration of Unmanned Aerial Vehicles (UAVs) within the construction industry. As a non-empirical investigation, the research relies on systematic literature analysis and conceptual reasoning to develop a structured understanding of UAV applications, benefits, and challenges.

a) Research Design

The paper is grounded in a qualitative, theory-driven design using a conceptual framework informed by Technological Innovation Theory (Dosi, 1982) and Diffusion of Innovations Theory (Rogers, 2003). These theories help explain the technological trajectory and adoption patterns of UAVs in construction contexts. The framework categorizes findings into four domains: (i) UAV applications, (ii) benefits, (iii) challenges, and (iv) integration strategies.

b) Data Collection

Secondary data collected from peer-reviewed journals, industry reports, and government regulations. Sources were identified using academic databases such as Scopus, ScienceDirect, and Google Scholar, with

search terms including "UAV in construction," "drone applications," "technological adoption in construction," and "construction safety and UAVs." Inclusion criteria focused on studies published between 2014 and 2024, particularly those addressing the Malaysian or Southeast Asian context.

c) Data Analysis

A thematic analysis approach was applied to identify and categorize key concepts emerging from literature. Themes were developed around UAV functions (e.g., site surveying, monitoring), benefits (e.g., safety, cost-efficiency), and challenges (e.g., regulatory issues, privacy concerns). These themes were then mapped onto the conceptual framework to explore theoretical relationships and inform recommendations.

d) Validation and Rigor

To ensure conceptual validity, cross-verification was conducted using triangulation from multiple scholarly sources and regulatory documents. Relevance and credibility of sources were confirmed through citation analysis and journal impact rankings. Additionally, expert opinions and industry white papers were reviewed to align academic findings with current industry practices.

IV. THEORETICAL AND CONCEPTUAL FRAMEWORK

The integration of Unmanned Aerial Vehicles (UAVs) in the Malaysian construction industry is best understood through two interrelated theoretical lenses: Technological Innovation Theory and Diffusion of Innovations Theory. These frameworks provide critical insights into the adoption patterns, technological trajectories, and operational impact of UAVs within construction environments.

e) Technological Innovation Theory

Rooted in the works of Dosi (1982), Technological Innovation Theory explains how industries undergo transformation through the introduction and application of novel technologies. In the construction sector, UAVs represent a disruptive innovation capable of redefining traditional workflows—such as site inspection, progress monitoring, and mapping by improving efficiency and reducing reliance on manual labor. This theory emphasizes the role of institutional and organizational capabilities in adopting and adapting new technologies. For instance, construction firms with greater digital infrastructure are more likely to integrate UAVs into their operations successfully.

f) Diffusion of Innovations Theory

Developed by Rogers (2003), this theory elucidates how, why, and at what rate new technologies spread across a population. The theory segments adopters into five categories: innovators, early adopters, early majority, late majority, and laggards. In the Malaysian construction context, the diffusion of UAVs is influenced by factors such as perceived relative advantage (e.g., cost and time savings), compatibility with existing systems, and observability of outcomes. Regulatory environments, training requirements, and cultural readiness also play significant roles in the rate of adoption.

g) Conceptual Framework

The conceptual framework synthesized from these theories proposes a multi-dimensional model for UAV integration. At the core is the adoption process, influenced by internal factors (e.g., organizational readiness, investment capacity) and external forces (e.g., regulations, technological availability). The framework identifies four operational domains:

1. Applications – Site surveying, safety inspections, progress monitoring.
2. Benefits – Improved accuracy, enhanced safety, reduced costs.
3. Challenges – Legal barriers, privacy issues, training gaps.
4. Strategic Enablers – Policy support, cross-sector collaboration, and innovation training.

By aligning theoretical constructs with practical applications, this framework provides a comprehensive lens for analyzing how UAVs can be effectively integrated into the Malaysian construction landscape.

V. DATA COLLECTION

Table 2.0 Data Collection Method

Method	Description	Purpose
Survey Questionnaires	Structured questions distributed to professionals (engineers, site managers).	To gather quantitative data on awareness, usage, and perception of UAVs in construction projects.

Semi-Structured Interviews	In-depth discussions with stakeholders such as regulatory bodies and UAV vendors.	To explore qualitative insights about regulatory challenges, benefits, and strategic enablers.
Focus Group Discussions	Small group sessions with construction workers or project leaders.	To assess community-level attitudes and practical experiences with UAV integration.
Document Analysis	Review of policy documents, construction guidelines, and UAV integration reports.	To extract secondary data on legal frameworks and industry adoption trends.
Case Studies	Examination of specific construction projects using UAVs in Malaysia.	To analyze real-life applications, operational benefits, and constraints.

h) Target Respondents

- Construction project managers
- Civil engineers and UAV operators
- Regulatory officers (CIDB, local authorities)
- Technology providers/vendors

i) Sampling Method

- **Purposive sampling**: Selecting participants based on expertise or experience with UAVs.
- **Snowball sampling**: Leveraging initial contacts to identify other qualified respondents.

To conduct a case study analysis for "The Integration of Unmanned Aerial Vehicles (UAVs) in the Malaysian Construction Industry" based on data collection methods, we would typically follow these steps:

A. *Literature Review & Secondary Data Collection:*
   - Review existing case studies, government reports, and construction industry documents related to UAV usage in Malaysia.
   - Identify relevant policies, such as regulations from the Civil Aviation Authority of Malaysia (CAAM), and the uptake of UAV technology in construction projects.

B. *Primary Data Collection:*
   - Survey Questionnaires: Distribute a structured questionnaire to construction professionals, such as project managers, engineers, and UAV operators in Malaysia.
   - Interviews: Conduct interviews with key stakeholders like construction firms, regulatory bodies, and UAV service providers to gather in-depth insights into challenges, adoption barriers, and benefits.

C. *Analysis of Results*: Based on the responses from the data collection (hypothetical case):

VI. FINDING

Based on Survey Result

Category	Indicator	Percentage (%)
Awareness	Awareness of UAVs in construction	80%
	Use of UAVs for site surveying and inspections	50%
Benefits Identified	Improved accuracy and data collection efficiency	70%
	Enhanced safety by reducing exposure to hazards	60%
Challenges Faced	Regulatory issues (e.g., CAAM regulations)	50%
	High initial UAV costs	45%
	Lack of skilled operators and training	30%
Adoption Rate	Large firms (fully integrated UAVs)	40%
	Small firms (UAV adoption limited due to cost)	15%

The survey results indicate strong awareness (80%) of UAV technology within Malaysia's construction industry, with 50% of respondents already applying UAVs in tasks such as site surveying. Key benefits include improved accuracy (70%) and enhanced safety (60%). However, challenges persist—regulatory issues (50%), high initial costs (45%), and a lack of skilled operators (30%) hinder broader adoption. Notably, UAV integration is more common in large firms (40%) than in smaller companies (15%), mainly due to cost barriers. These findings

highlight both the growing potential and the current limitations of UAV adoption in Malaysian construction practices.

For interview finding:

- Regulatory Challenges:
  - Regulatory bodies report ongoing efforts to refine UAV regulations for the construction sector, but some ambiguity remains regarding airspace usage and flight permissions.
  - Industry experts argue for clearer guidelines to enable broader adoption.
- Strategic Enablers:
  - Participants emphasized the importance of public-private collaboration and government incentives to reduce the cost of UAV technology.
  - Companies are beginning to see the value of cross-sector partnerships, with several firms working with UAV vendors to pilot programs.

Case Study Example:

- Project: The Klang Valley Mass Rapid Transit (MRT) Line 2.
  - UAVs were used for site surveying and progress monitoring, helping to speed up the process and improve the accuracy of data collected.
  - Benefits: Reduced the need for manual inspections, saving time and lowering safety risks.
  - Challenges: Delays in getting regulatory approvals and the cost of UAV equipment.

Drone technology is becoming increasingly important in the construction industry in Malaysia. Companies are using drones for tasks like surveying, data collection, and site inspections. This paper highlights several companies in Malaysia, such as Aerodyne Group, vstream Revolution Sdn Bhd, MUDAS, and Lestari Aero Industries Sdn Bhd, that are leading the way in applying drone technology. These companies are also working with universities to develop research and improve skills in this field.

Company Name	Job/Role	Citation
Aerodyne Group	A provider of drone technology solutions, data, and digital transformation (DT^3). They focus on smart city and agriculture sectors and have partnered with Celcom Axiata for IR4.0 development.	Aerodyne Group has collaborated with Celcom Axiata Berhad for IR4.0 solutions, focusing on urban and agricultural sectors.
VStream Revolution Sdn Bhd	A company collaborating with Universiti Tun Hussein Onn Malaysia (UTHM) on research and innovation in drone technology, including knowledge-sharing, staff and student development, and training programs.	VStream Revolution has partnered with UTHM for drone technology research, focusing on knowledge sharing and skill development.
Malaysia Unmanned Drones Activists Society (MUDAS)	Collaborates with UTHM to enhance drone technology expertise among university staff and students, fostering skills and research in the field.	MUDAS works with UTHM to strengthen drone technology expertise among staff and students, supporting research and skills development.
Lestari Aero Industries Sdn Bhd	Involved in collaboration with UTHM for drone technology research, knowledge sharing, training programs, and staff and student development.	Lestari Aero Industries partners with UTHM in research on drone technology, focusing on knowledge-sharing and development.

CONCLUSION

The integration of Unmanned Aerial Vehicles (UAVs) into the construction industry has the potential to significantly transform various aspects of project management, from site surveying and progress monitoring to safety inspections. UAVs enhance operational efficiency, improve data accuracy, and minimize human exposure to hazardous environments, aligning with the ongoing trend of digitalization and automation in construction.

However, the widespread adoption of UAVs faces challenges related to regulatory hurdles, privacy concerns, and the need for specialized training.

While UAVs have proven their value in terms of cost reduction, safety enhancement, and workflow optimization, the successful integration of this technology depends on addressing these challenges. Theoretical frameworks, such as the Diffusion of Innovations Theory and the Technology Acceptance Model, provide useful lenses to understand the factors influencing UAV adoption in construction. Nonetheless, gaps remain in empirical research, particularly regarding the long-term impact of UAV integration on project outcomes, and the development of standardized regulations for UAV operations.

Future research should focus on validating UAV integration through case studies, exploring the long-term effects on construction efficiency and safety, and investigating the role of emerging technologies like AI in further enhancing UAV capabilities. Furthermore, it is crucial to develop clear guidelines that address ethical and regulatory concerns to ensure the responsible and effective use of UAVs in the industry. Ultimately, the integration of UAVs in construction represents a critical step towards optimizing construction practices, improving safety standards, and contributing to the realization of Construction 4.0.

ACKNOWLEDGMENT

I would like to extend my heartfelt thanks to the Department of Building Surveying at UiTM Perak Branch, particularly my supervisor, for their invaluable assistance, unwavering dedication, and support in funding this publication. I am also grateful for the help I received in gathering essential research data from the relevant authorities, organizations, and management teams of the historical sites involved in this study. My sincere appreciation goes to my family and friends for their continuous encouragement and support throughout this academic journey. I am truly grateful to all of you.

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DIGITAL TRANSFORMATION IN PROPERTY MANAGEMENT: ADOPTION CHALLENGES AND STRATEGIES FOR OVERCOMING BARRIERS

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ABSTRACT

In property management, digitalisation has become an innovator, improving sustainability, operational effectiveness, and tenant happiness. This study assesses how well digital solutions like blockchain, smartphone applications, and the Internet of Things (IoT) streamline communication, financial transactions, and building upkeep. This study aims to create a comprehensive review and provide a framework for property managers, particularly the challenges for digitalisation in property management. To achieve this, both empirical and conceptual papers were reviewed. The keywords 'digitalisation', 'digital technology', 'challenges digital adoption', 'obstacles and barriers', and 'property management' led to the discovery of a total of 1,243 articles in several e-databases. Following the filtration process, 27 full-text papers relevant to the subject were chosen for review. The study found three main types of digitalization adoption: mobile apps, which make it easier for tenants to interact with each other; blockchain, which ensures safe and open data management; and the Internet of Things, which makes it easier to monitor building systems in real time. The review identified five key challenges in adopting this digital technology in property management, namely excessive high cost implementation, insufficient financial resources, lack of skills, barriers in technology support, barriers in the organizational. Digital adoption can be further maximized by putting best practices, like benchmarking, operational efficiency evaluations, and sustainable scalability models, into practice. By addressing these challenges, property management firms can enhance service quality, reduce operational costs, and create a more responsive and technology-driven ecosystem. This research contributes to the growing body of knowledge on digital transformation in property management, providing practical insights for industry practitioners and policymakers.

Keywords: Digitalisation, Digital Adoption, Property Management, Technological Innovation,

I. INTRODUCTION

Digitalisation profoundly alters organisational communication. The methods by which teams communicate and share information have evolved due to the advent of digital platforms, collaborative tools, and real-time communication technologies (Lang & Lang, 2021; Leonardi & Meyer, 2015). Digital communication channels eliminate geographical borders, facilitating seamless collaboration among dispersed teams (Lanzolla et al., 2020). Moreover, the incorporation of chatbots and virtual assistants enhances efficiency by optimising internal communication processes. A fundamental principle of digital organisational processes is data-driven decision-making (Davenport et al., 2010). The integration of advanced analytics with extensive data from multiple sources empowers organisations to make informed decisions (Colombari et al., 2023). Digitalisation enhances the precision and responsiveness of decision-making processes, utilising real-time data for operational adjustments and predictive analytics for strategic decisions.

Digitalisation is revolutionizing the property management industry, driving significant improvements in efficiency, sustainability, and tenant satisfaction. The increasing integration of digital technologies has reshaped traditional management practices, offering innovative solutions to streamline operations and enhance service

delivery. Property managers are leveraging cutting-edge tools such as blockchain for secure financial transactions, mobile applications for seamless tenant interactions, and the Internet of Things (IoT) for real-time building monitoring and maintenance. These advancements not only improve operational workflows but also contribute to data-driven decision-making, predictive maintenance, and energy-efficient building management. In the last hundred years, property management has evolved into a profession focused on maximising the value of income-generating real estate assets (Goss and Campbell, 2008; Klink, 2019). Consequently, individuals working in the sector are now required to perform a diverse array of tasks that were before beyond the scope of the typical property manager's duties (Read and Carswell, 2019). Establishing and implementing procedures to deliver outstanding customer service is one such initiative (Palm, 2011). Customer service methods enhance value by aiding real estate owners in recruiting, keeping, and securing premium rentals (Sanderson, 2019). As a result, digitalization fosters a more transparent, cost-effective, and responsive property management ecosystem.

II. DIGITAL TRANSFORMATION IN PROPERTY MANAGEMENT

a. *Mobile Application*

Digitalization in property management is crucial for enabling tenant-focused strategies that enhance communication, convenience, and overall satisfaction. With increasing expectations for seamless and responsive services, digital tools have become essential for improving tenant experiences and streamlining property management operations. Mobile application, commonly known as “mobile app” is computer programme software (Jans- sen, n.d.) especially developed for smart phones (Lockergnome.net, 2012). Mobile applications serve as a vital bridge between renters and property managers, offering real-time issue reporting, automated maintenance requests, efficient payment processing, and instant access to lease agreements, billing details, and other property-related information. These solutions foster a more transparent and responsive relationship, allowing tenants to interact with management at their convenience and ensuring that their concerns are addressed promptly. Beyond mobile applications, emerging technologies such as blockchain and the Internet of Things (IoT) further enhance tenant highlight how blockchain’s secure and immutable ledger ensures transparency in financial transactions, lease agreements, and data sharing, reducing disputes and fostering trust between tenants and landlords. Meanwhile, IoT-powered smart building systems enable real-time monitoring and automation of essential services, such as climate control, security access, and predictive maintenance. These technologies work together to create a more intelligent, efficient, and tenant-centric property management ecosystem. The integration of these digital solutions illustrates the extensive ramifications of digital transformation in property management. By leveraging technology, property managers can provide proactive services, improve operational efficiency, and ensure a seamless living experience for tenants.

b. *Blockchain and data security*

The main ledger for the widely used cryptocurrency Bitcoin is referred to as Blockchain. An unidentified person known as "Satoshi Nakamoto" created Bitcoin in 2008, and subsequently, in 2009, blockchain technology was implemented as an independent technology across several sectors (Zheng et al ,2017) assert that a blockchain functions as a public ledger comprising a series of blocks that encompass all executed transactions. The chain expands with each newly added block, rendering the existing blocks increasingly resistant to tampering and immutable. Its features include distributed consensus mechanisms and asymmetric cryptography, employed to ensure ledger integrity and user security. The primary features of blockchain technology include decentralisation, permanence, anonymity, and auditability. Blockchain technology aspires to integrate into network monitoring and security services, including authentication, privacy, secrecy, integrity, and provenance (Salman et al. 2018). At present, dependable third-party brokers provide and facilitate these services, or inefficient ways are utilised. Considering the preceding, security becomes a critical issue for contemporary applications Salman et al. (2018, p. 858) assert that blockchain technology provides a completely distributed, provably secure, and consensus-based solution, along with security assurances that mitigate numerous traditional problems. Despite blockchain technology being a primary catalyst for modern networking and security research, as previously indicated, there is less understanding of how professionals in these sectors perceive the future transition to blockchain-based applications.

c. *Internet of Things (IoT)*

As the demand intensifies to optimize resources at scale for regulatory compliance, energy efficiency, and enhanced tenant services, Internet of Things (IoT) technologies are becoming a dominant force across multiple stakeholders in the multi-dwelling unit (MDU) sector. Property managers, building owners, and technology providers are increasingly recognizing the potential of IoT-driven solutions to streamline operations, enhance security, and improve tenant experiences. These smart technologies allow for real-time monitoring of utilities,

predictive maintenance, automated lighting and climate control, and seamless access management, all of which contribute to operational efficiency and cost savings. According to experts at Parks Associates, nearly one-third of MDU property managers in the United States report offering renters IoT-enabled smart home devices in at least one of their properties (Reza Raji, 2023). This adoption reflects the growing expectations among tenants for connected living spaces equipped with intelligent systems that enhance convenience, security, and energy conservation. From keyless entry and remote-controlled thermostats to AI-driven maintenance alerts, IoT is reshaping the rental market by offering more personalized and data-driven services. As this trend gains momentum, the property management industry is uniquely positioned to bridge the gap between tenants' digital lifestyles and their physical living environments. The integration of IoT-based services in apartments, condominiums, and other multi-dwelling units is not just an added convenience but a transformative shift that is redefining value propositions in the sector. Smart property management platforms, powered by IoT, can optimize space utilization, ensure regulatory compliance, and create new revenue streams through value-added services. By embracing IoT technologies, the MDU sector is paving the way for a smarter, more efficient, and tenant-centric housing ecosystem. The ongoing advancements in connectivity and automation are setting new industry standards, demonstrating that IoT is no longer a luxury but a necessity for future-ready property management.

III. RESEARCH METHODOLOGY

This study examines the digital transformation in property management and challenges of digital adoption. To fulfil the research objective, a review of both empirical and conceptual articles was conducted (see Figure 1 for flowchart). A total of 1,243 articles were identified throughout several electronic databases utilising the keywords: 'digitalisation,'digital technology,' 'challenges digital adoption,' 'obstacle and barriers,' and 'property mangement'. A total of 27 full-text publications pertinent to the issue were selected for evaluation after the filtration procedure. Based on these publications, five key challenges in digital adoption have been identified namely excessive high cost implementation, insufficient financial resources, lack of skills, barriers in technology support, barriers in the organizational. Table 1 presents the matrix for these main challenges.

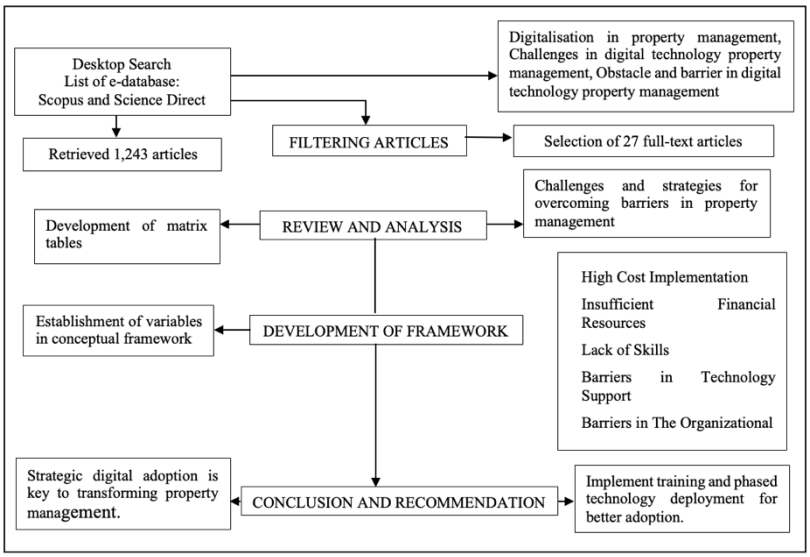


Figure 1.0 *Flowchart of review procedures*

Table 1.0 *The matrix table of challenges in digital adoption in property management*

Authors	Saxena	Christian Klee	Prasetya Cahya S, Arief Ramadhan	Olivia Tiku	Alouis Chilunjika	Juan Ocampo, Dirk Schneckenberg	Muhammad Ali Musarat, Wesam Salah Alaloul, Siti Mariam Binti Zainuddin, Abdul Hannan Qureshi, Absen Maqsoom	Frequency
Year Of Publication	2022	2022	2022	2023	2024	2024	2024	
Challenges Of Sustainable Implementation In Digital Property Management								
High Cost Implementation			✓	✓	✓		✓	∑ 4
Insufficient Financial Resources				✓	✓			∑ 2
Lack Of Skills		✓		✓		✓	✓	∑ 4
Barriers in technology support			✓	✓	✓	✓		∑ 4
Barriers In Organizational	✓	✓		✓	✓	✓		∑ 5

IV. CHALLENGES AND STRATEGIES FOR OVERCOMING BARRIERS

While digitalization presents significant opportunities for the property management industry, its implementation is not without obstacles. The transition to a technology-driven ecosystem requires substantial investment, strategic planning, and a shift in organizational mindset to fully realize its potential. Despite the promising benefits, the widespread adoption of digital solutions faces several challenges. High implementation costs pose a significant financial burden, particularly for small and mid-sized property management firms. Additionally, the absence of well-defined legal frameworks and regulatory guidelines complicates compliance and data governance. A lack of expertise and technical knowledge among property managers further slows the transition, while resistance to change from stakeholders creates additional barriers. Moreover, cybersecurity threats raise concerns about data privacy and system vulnerabilities, necessitating robust security measures.

1. *High Cost Implementation*

For many poor countries, including BMS, securing funding for revolutionary projects is a major challenge. Building management systems (BMS) require significant investment in hardware, software, installation, and staff training (Tiku, 2023). Inflationary pressures and budget constraints that hindered the transition to a digital system, caused delays in the implementation of Integrated Estate/Property Management System. High costs of system installation and maintenance were a barrier (Chilunjika, 2023; Chilunjika, Mutema and Dube, 2021). The implementation of technologies such as IoT, AI, and BIM requires significant investments in infrastructure, software, and workforce training. After the Covid-19 pandemic started to slow down, investment growth in the Asia Pacific region's real estate market increased by 21% in 2021 (Bogataj 2020). large upfront expenses associated with putting digital technologies, standards, and specifications into practice (Al-Ashmori, Othman, Al-Aidrous, 2022).

2. *Insufficient Financial Resources*

Despite stakeholder engagement, there are still many obstacles to overcome, especially when government funding is scarce (Tiku, 2023). Over the years, we have held numerous workshops to try to implement digitalized property management systems, but senior managers consistently point out that there is a lack of funding. Although it cannot be disputed that financial constraints are one of the problems for the adoption of a property management system (Halvitagala and Gordon, 2014; McGill et al., 2011; Worley International Ltd, 2000).

3. *Lack of skills.*

A widespread skills deficit may make it difficult to adopt and operate BMSs, which would undermine the industry's attempts to attain sustainability and energy efficiency (Tiku, 2023). Due to a lack of skilled people and slow economic advancement, this sector is poorly equipped to handle digital change (Pfnür and Wagner, 2020). Startups often do not understand the complex needs and work processes of real estate companies (Ocampo and Schneckenberg, 2022). Lack of trained professionals or trainees to manage the digitalization process is another major challenge (Musarat, Alaloul, Zainuddin, Qureshi, Maqsoom, 2024).

D. Barriers in technology support

Due to their heavy reliance on digital infrastructure, Building Management System integration and operation are significantly hampered by limited ICT connectivity. For Building Management System to operate at their best, strong and dependable ICT connectivity is typically necessary (Tiku, 2023). According to the study, the digital divide is another obstacle that must overcome to deploy Integrated Property Management System (Halvitagala and Gordon, 2014; McGill et al., 2011; Worley International Ltd, 2000). Several articles give a summary of the model used to understand how digital transformation is occurring in the property management sector (Bogataj et al, 2020). Technology and digitalization must be given more weight in Real Estate operations (Ocampo and Schneckenberg, 2022).

d. *Barriers in the organizational.*

The cultural norms and values that are prevalent also have a significant impact on the adoption and functioning of BMS (Tiku, 2023). Not all employees have the same interest in digitalization (Ulukan, 2020). Resistance to change in government institutions that still maintain traditional methods. Old officials often become "gatekeepers" who reject new systems because they want to maintain the status quo and existing structures. They always say that we have been doing things this way for the last twenty years (Saxena et al., 2020). Older officials tend to reject innovation and are more comfortable with old systems. The fact that some of the leaders are elderly and, in spite of their years of expertise, are still used to doing things the old-fashioned manner presents problems for us. When it comes to change, they are reluctant to it and want to do things in the traditional manner. Our leaders are determined to stick with the current systems even though we have been advocating for technological changes (Halvitagala and Gordon, 2014; McGill et al., 2011; Worley International Ltd, 2000). Companies often have complex hierarchies and are inflexible in accepting new technologies (Ocampo and Schneckenberg, 2022).

CONCLUSION

This study provides a comprehensive review of digitalization in property management, assessing the effectiveness of key digital tools and identifying the major obstacles to implementation. By analyzing 27 relevant studies from a pool of 1,243 articles, this research highlights the importance of strategic digital adoption, including stakeholder engagement, structured training programs, and phased technology deployment. Additionally, government incentives and regulatory support play a crucial role in fostering a more inclusive digital transformation. Implementing best practices such as benchmarking, operational efficiency assessments, and scalability models can further optimize digital adoption. This research contributes valuable insights for property managers, industry practitioners, and policymakers, aiming to create a more technology-driven and efficient property management ecosystem.

ACKNOWLEDGMENT

The authors would like to express their gratitude to College of Built Environment, UiTM Perak branch for funding this publication.

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MAXIMIZING OPERATIONAL EFFICIENCY IN FACILITY MANAGEMENT THROUGH IoT

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ABSTRACT

The integration of Internet of Things (IoT) technology in Facility Management (FM) presents significant opportunities for enhancing operational efficiency and sustainability in building operations. This study examines the challenges, applications, and potential benefits of IoT implementation in FM through a quantitative method using questionnaire surveys. The respondents are FM professionals in Malaysia. The research has two objectives, namely (i) to identify the challenges associated with IoT implementation in FM, and (ii) to determine the relevancy of IoT applications for FM efficiency. Through analysis of responses from FM professionals, the study reveals nine challenges in IoT integration, namely, (i) lack of standardization among IoT devices, (ii) data security concerns, (iii) high initial investment costs, (iv) insufficient technical expertise, (v) integration with existing systems, (vi) maintaining and managing, (vii) regulatory compliance, (vii) interoperability issues with IoT devices from different manufacturers and (ix) culture towards adopting new technologies. The findings indicate that IoT applications are particularly effective in resource allocation, energy management, and environmental monitoring, contributing to both operational efficiency and sustainability goals. This research provides valuable insights for FM practitioners and organizations considering IoT implementation, highlighting both the obstacles to be addressed and the potential benefits to be gained from successful integration of IoT technologies in FM operation.

Keywords: Internet of Thing, Facilities Management, Operational Efficiency

I. INTRODUCTION

In recent years, the Internet of Things (IoT) has become an innovative approach to improving operational efficiency in facilities management (FM). FM encompasses a wide range of actions to preserve constructed facilities' functioning, comfort, safety, and efficiency. Mannino et al. (2021) state that IoT devices can improve several facilities management activities, including inventory management, building security, energy control, and lifecycle monitoring of building components.

Pratap et al. (2024) state that operational efficiency may be significantly improved with IoT integration by decreasing maintenance costs, increasing occupant satisfaction, and decreasing downtime. Facilities operational and maintenance phases constitute a significant percentage of overall yearly operating expenses (50-70%). Integrating IoT with Building Information Modelling (BIM) enables facility managers to gather and analyze various data from multiple stakeholders. This integration optimizes data management and elevates building performance while facilitating decision-making (Mannino et al., 2021). Nevertheless, problems must be overcome, including data security concerns, device compatibility issues, and the requirement for experienced individuals to administer IoT systems to optimize the potential advantages.

In modern era today, the dynamic nature of sustainability imperatives, shaped by evolving legislation and societal expectations, complicates accurate forecasting in FM (Okoro, 2023). A significant issue arises from the insufficient involvement of FM personnel in developing BIM models, which often results in models lacking essential maintenance-related information. This disconnect can lead to forecasting inaccuracies regarding maintenance needs, as the BIM models may not accurately represent the actual conditions and requirements of the facilities (Villa et al., 2021). According to the author, leveraging real-time data from IoT sensors can significantly enhance forecasting accuracy. By incorporating IoT data into BIM models, facility managers are better equipped to monitor and evaluate building performance, ultimately leading to more precise predictions of maintenance requirements.

This research objectives are to (i) determine the relevancy of IoT applications that are suitable to FM efficiency.and (ii) to identify the challenges associated with the implementation of IoT in FM.

II. LITERITURE REVIEW

Benefits Of Iot

i. Automation of Processes

IoT enables the automation of routine tasks, reducing the need for manual intervention. For example, smart sensors can automatically adjust lighting and HVAC systems based on occupancy, leading to energy savings and improved comfort (Moudgil et al., 2023). IoT systems can automate the generation of reports and alerts for facility managers. This automation reduces the manual effort required for monitoring and reporting, allowing staff to focus on more strategic tasks (Batista et al., 2023).

IoT enables the automation of routine tasks and processes. For example, smart sensors can automatically adjust lighting, heating, or cooling based on occupancy, reducing energy consumption and operational costs (Khatib et al., 2023). IoT can automate various operational processes, such as lighting control, HVAC systems, and security measures. Automation reduces the need for manual intervention and ensures that systems operate at optimal levels, further enhancing efficiency (Sidek et al., 2022).

ii. Real-Time Data Collection and Analysis

IoT devices continuously collect data from various sources, providing real-time insights into operations. This data can be analyzed to identify inefficiencies, monitor performance, and make informed decisions quickly (Moudgil et al., 2023). IoT devices enable continuous monitoring of various parameters, such as water consumption, energy usage, and environmental conditions. This real-time data allows facility managers to identify issues promptly, such as leaks or equipment malfunctions, leading to quicker responses and reduced downtime (Batista et al., 2023).

IoT devices continuously collect data from various sources, providing real-time insights into operations. This data can be analyzed to identify inefficiencies, monitor performance, and make informed decisions quickly (Khatib et al., 2023). IoT devices enable continuous monitoring of facility conditions, such as temperature, humidity, and occupancy levels. This real-time data allows facility managers to make informed decisions quickly, optimizing resource usage and improving overall operational efficiency (Sidek et al., 2022).

iii. Reduce Waste

By monitoring equipment conditions through IoT sensors, organizations can predict when maintenance is needed before a failure occurs. This proactive approach minimizes downtime and extends the lifespan of assets, ultimately leading to cost savings and improved operational continuity (Moudgil et al., 2023). IoT sensors can predict when equipment fails or requires maintenance, allowing for proactive interventions. This predictive approach reduces unexpected breakdowns and extends the lifespan of building systems, contributing to overall operational efficiency (Batista et al., 2023).

This proactive approach minimizes downtime, extends the lifespan of assets, and reduces maintenance costs, leading to more efficient operations (Khatib et al., 2023). Organizations can predict when equipment will likely fail or require maintenance by analyzing data collected from IoT sensors. This proactive approach reduces downtime and maintenance costs, ensuring facilities operate smoothly and efficiently (Sidek et al., 2022).

iv. Resource Allocation

IoT can allocate resources such as energy, water, and materials. For instance, smart meters can track energy consumption patterns, allowing organizations to adjust usage and reduce waste (Moudgil et al., 2023). Organizations can optimize resource usage by analyzing data from IoT devices like water and energy. For instance, IoT functionalities allow for identifying high-consumption areas and implementing strategies to reduce waste, leading to significant cost savings and improved sustainability (Batista et al., 2023). IoT integration allows for better tracking and managing resources like energy and water. For instance, smart meters can provide insights into consumption patterns, enabling facility managers to implement energy-saving measures and reduce waste (Sidek et al., 2022). Implementing a centralized IoT management platform can streamline the integration process. Such platforms can provide a unified interface for monitoring and controlling various IoT devices, making it easier to manage data flows, enforce security policies, and ensure compatibility across different systems (Ruiz-Zafra et al., 2022).

v. Enhanced Communication and Collaboration

IoT facilitates better communication between devices and systems, improving collaboration across departments. For example, IoT-enabled platforms can integrate data from various sources, providing a holistic view of operations and enabling teams to work more effectively together (Moudgil et al., 2023).

IoT can be integrated with other technologies, such as AI and machine learning, to further enhance operational efficiency. For example, AI algorithms can analyze IoT data to optimize processes and predict future trends (Khatib et al., 2023). IoT facilitates better communication between different systems and stakeholders. For example, real-time alerts can be sent to maintenance teams when issues arise, allowing quicker response times and minimizing disruptions to operations (Sidek et al., 2022).

vi. Improved Decision-Making

The insights gained from IoT data analytics empower managers to make data-driven decisions. This can lead to more strategic planning, better resource allocation, and enhanced overall performance (Moudgil et al., 2023). The integration of IoT with BIM provides a wealth of operational data that can be analyzed to inform decision-making. By establishing consumption patterns and identifying anomalies, managers can make informed choices about resource allocation and maintenance schedules, ultimately improving efficiency (Batista et al., 2023).

The vast amount of data generated by IoT devices can be analyzed to identify trends and areas for improvement. This data-driven approach enables facility managers to make strategic decisions that enhance operational efficiency and service delivery (Sidek et al., 2022). With real-time data and analytics access, decision-makers can respond quickly to changing conditions and make data-driven decisions that enhance operational efficiency (Khatib et al., 2023).

vii. Increased Flexibility and Scalability

IoT systems can be easily scaled and adapted to changing operational needs. Organizations can add new devices or functionalities as required, allowing for greater flexibility in operations (Moudgil et al., 2023). By improving operational efficiency through IoT, buildings can better meet sustainability targets. Efficient resource management reduces environmental impact, aligning with broader sustainability initiatives and standards (Batista et al., 2023). Organizations can achieve significant cost savings by improving operational efficiency through IoT integration. Reduced energy consumption, lower maintenance costs, and optimized resource allocation contribute to a more sustainable and financially viable operation (Sidek et al., 2022). Keeping IoT devices and software up to date is crucial for maintaining security and operational efficiency. Regular updates can patch vulnerabilities and improve functionality, while proactive maintenance can prevent system failures and downtime (Ruiz-Zafra et al., 2022).

viii. Enhanced Customer Experience

IoT integration can improve the overall experience for building occupants by ensuring optimal conditions and providing timely information about facility usage. This can increase users' satisfaction and productivity(Batista et al., 2023). Organizations can improve service delivery and customer satisfaction by utilizing IoT to monitor and respond to customer needs in real-time. For example, intelligent building systems can adjust environments based on user preferences, creating a more comfortable experience (Moudgil et al., 2023). Organizations can better understand customer preferences and behaviours by leveraging IoT data, improving service delivery and customer satisfaction (Khatib et al., 2023). Educating building managers and staff about IoT technologies, security practices, and data management can enhance operational efficiency. Training can empower users to make informed decisions regarding IoT device usage and data handling, ultimately contributing to a more secure and efficient environment (Ruiz-Zafra et al., 2022).

ix. Sustainability Metrics

IoT integration can streamline the collection and reporting of sustainability metrics, making it easier for organizations to comply with regulations and standards related to environmental performance (Okoro, 2023). Chen and Jin (2012) proposed that the crucial technology of IoT will be widely applied in many areas, including digital agriculture, smart grids, smart homes, intelligent transportation, smart logistics, disaster monitoring, and remote medical care. This metric assesses suppliers' sustainability practices and the supply chain's overall environmental impact. It includes evaluating supplier compliance with environmental standards and the carbon footprint of logistics (Rahimi et al., 2024).

Challenges In Iot Implementation

5) Interoperability Issues

One of the major challenges in implementing IoT is the lack of standardized protocols and interoperability among various IoT devices and systems, which can lead to integration difficulties and hinder seamless communication and data exchange (Anathan et al., 2023). According to Villa et al.

(2021), without effective communication and data sharing across different systems, the full advantages of IoT cannot be achieved. The presence of diverse communication protocols among different devices complicates the creation of a cohesive IoT ecosystem (Pratap et al., 2024). Furthermore, inconsistent standards can result in vulnerabilities and complicate data management (Pathmabandu et al., 2023).

x. *Data Security and Privacy*

The collection and transmission of data via IoT devices raise significant concerns regarding the security of sensitive information and the risk of data breaches (Ehab et al., 2024). The integration of these devices heightens susceptibility to cyberattacks, which can threaten data integrity and privacy. Therefore, it is crucial to implement strong security measures to safeguard sensitive information (Anathan et al., 2023). Organizations must adopt comprehensive cybersecurity protocols to protect sensitive data from breaches and unauthorized access (Pratap et al., 2024). Additionally, IoT devices have the capacity to collect sensitive information, leading to worries about how this data is utilized, particularly in marketing and service delivery contexts (Pathmabandu et al., 2023).

xi. *Scalability*

IoT systems are significantly dependent on stable internet connections. Unreliable network connectivity can hinder the operation of IoT devices, resulting in delays in data collection and processing (Anathan et al., 2023). According to Dai et al. (2023), there is a need for increased efforts to enhance the scalability and reliability of IoT platforms, as many current systems mainly offer daily monitoring without sophisticated predictive capabilities. Furthermore, Villa et al. (2021) emphasize that the proposed IoT systems should be adaptable and scalable to incorporate additional sensors and nodes as needed by end-users.

xii. *Integration with Existing Systems*

Integrating IoT solutions with existing infrastructure and systems can pose challenges, potentially resulting in compatibility issues (Ehab et al., 2024). The sheer volume of data produced by IoT devices can be daunting to collect, process, and store. Problems concerning data accuracy, reliability, and integration with current systems may impede effective data usage (Anathan et al., 2023). According to Bechina and Arntzen (2022), a smooth integration of real-time IoT data is essential for successful predictive maintenance; however, achieving this level of integration can be quite complicated

xiii. *Data Management and Analytics*

To analyze and derive actionable insights from the large volumes of data produced by IoT devices (Ehab et al., 2024). The incorporation of IoT devices heightens the risk of cyberattacks, which can jeopardize data integrity and privacy. Therefore, implementing strong security measures is crucial to safeguard sensitive information (Anathan et al., 2023). According to Bechina and Arntzen (2022), effective data management and analysis are necessary to obtain valuable insights, yet organizations may lack the capabilities required to process and analyze this data efficiently.

xiv. *Cost of Implementation*

The upfront costs associated with implementing IoT systems can be considerable, potentially discouraging organizations from embracing the technology (Ehab et al., 2024). Although IoT has the potential to lower operational expenses over time, the initial outlay for IoT infrastructure, devices, and training can be substantial, creating a barrier to adoption for certain organizations (Anathan et al., 2023). This encompasses expenses related to acquiring devices, installing sensors, and system integration (Bechina & Arntzen, 2022).

xv. *Lack of Skilled Personnel*

A common issue is the scarcity of skilled professionals who possess expertise in IoT technologies, which can impede effective implementation and management (Ehab et al., 2024). For successful IoT deployment, it is essential that employees receive adequate training to utilize new technologies and adjust to changes in workflows; this can be particularly challenging in organizations with differing levels of technological competence (Anathan et al., 2023). According to Sidek et al. (2022), there is considerable internal resistance from employees when adopting IoT-based services, often arising from a lack of preparedness to embrace change and utilize new technologies, which can obstruct the successful implementation of IoT solutions. Additionally, Pratap et al. (2024) note that there is frequently a deficiency of skilled personnel capable of effectively managing and analyzing the data produced by IoT systems.

xvi. *Regulatory Compliance*

Navigating the regulatory framework concerning data protection, privacy, and environmental standards poses significant challenges for organizations deploying IoT solutions. While compliance with these regulations is crucial, it can complicate the process of adopting IoT technologies (Pratap et al., 2024). According to Pathmabandu et al. (2023), compliance necessitates continuous monitoring and adjustment of policies and practices to ensure the proper protection of user data. Furthermore, IoT solutions must conform to applicable laws and standards, which may differ by region (Bechina & Arntzen, 2022).

xvii. *User Acceptance and Change Management*

Users frequently remain unaware of the data being gathered and its applications. This lack of clarity can foster distrust and hesitation towards engaging with IoT technologies (Pathmabandu et al., 2023). Change management is identified as one of the primary challenges organizations face, especially in addressing employees' concerns and capabilities regarding new technologies (Sidek et al., 2022). According to Bechina & Arntzen (2022), resistance to change from both staff and management can hinder the effective implementation of IoT technologies in facilities management.

III. RESEARCH METHOD

The location of this study is Penang. The mall commonly has the title of facility manager, manager operation, manager maintenance, manager engineer, and technicians for the interview and distribution of the questionnaires.

SPSS was used to analyze the study's data. A collection of applications for altering, analyzing, and displaying data. This study was utilized to calculate IoT's frequency, percentage, mean, and standard deviation in FM.
This study used Penang Island as the target population for this study. Penang Island has 36 high-rise commercial buildings, with a total population size of 300. Each building has eight respondents representing various job roles, including Facility Manager, Building Manager, Facility Maintenance Manager, Facility Coordinator, Space Planner, Safety and Health Officer, Engineer, and Technician. The research targeted a sample size of 169 respondents. According to Nulty (2008), the overall response rate for online data collection is approximately 32.6%, which validates the continuation of the survey. Based on this rate, it was expected to receive about 55 valid responses. However, the study successfully gathered 71 respondents, resulting in a response rate of 42.01%. The variables data research involved interviews with five respondents: one Facility Manager, one Assistant Facility Manager, and three Engineers. The questionnaires were developed based on secondary data to gather insights from these experts, allowing for the verification of variable data through their expertise.

Table 1.0: Percentage and Receive Questionnaire for Data Analysis

Sample	Receive Questionnaire	Percentage Received
169	71	42.01%

IV. DISCUSSION AND FINDINGS

a. To Identify the Challenges Associated with the Implementation of IoT in FM

Objective one is the implementation of IoT in FM faces several challenges that can be categorized into nine key constructs namely, (i) lack of standardization among IoT devices, (ii) data security concerns, (iii) high initial investment costs, (iv) insufficient technical expertise, (v) integration with existing systems, (vi) maintaining and managing, (vii) regulatory compliance, (vii) interoperability issues with IoT devices from different manufacturers and (ix) culture towards adopting new technologies.

Table 2.0: Mean Factors for Nine Constructs of Challenges Associated with The Implementation of IoT In FM

Construct	Level of Challenges	Frequency	Percentages (%)	Mean
Lack of standardization among IoT devices	Not Challenges	10	14.1	3.28
	Less Challenges	5	7.0	
	Neutral	22	31.0	
	Challenges	23	32.4	
	Most Challenges	11	15.5	
Data security concerns	Not Challenges	8	11.3	3.56
	Less Challenges	6	8.5	
	Neutral	17	23.9	
	Challenges	18	25.4	
	Most Challenges	22	31.0	
High initial investment costs	Not Challenges	6	8.5	3.46
	Less Challenges	12	16.9	
	Neutral	12	16.9	
	Challenges	25	35.2	
	Most Challenges	16	22.5	
Insufficient technical expertise	Not Challenges	6	8.5	3.24
	Less Challenges	15	21.1	
	Neutral	20	28.2	
	Challenges	16	22.5	
	Most Challenges	14	19.7	
Integration with existing systems	Not Challenges	7	9.9	3.66
	Less Challenges	6	8.5	
	Neutral	13	18.3	
	Challenges	23	32.4	
	Most Challenges	22	31.0	
Maintaining and managing	Not Challenges	10	14.1	3.42
	Less Challenges	8	11.3	
	Neutral	19	26.8	
	Challenges	10	14.1	
	Most Challenges	24	33.8	
Regulatory compliance	Not Challenges	7	9.9	3.32
	Less Challenges	12	16.9	
	Neutral	18	25.4	
	Challenges	19	26.8	
	Most Challenges	15	21.1	
Interoperability issues with IoT devices from different manufacturers	Not Challenges	8	11.3	3.41
	Less Challenges	10	14.1	
	Neutral	14	19.7	
	Challenges	23	32.4	
	Most Challenges	16	22.5	
Culture towards adopting new technologies	Not Challenges	9	12.7	3.38
	Less Challenges	8	11.3	
	Neutral	16	22.5	
	Challenges	23	32.4	
	Most Challenges	15	21.1	

Referring to the tabulated in Table 2.0, the implementation of IoT in FM faces several challenges that can be categorized by their severity. The most critical challenges include system integration difficulties (mean score 3.66), data security concerns (3.56), and substantial initial investment requirements (3.46). At a moderate level of concern, facilities managers grapple with IoT system maintenance and management (3.42), device interoperability issues (3.41), and cultural resistance to new technology adoption (3.38). Less pressing but still significant challenges include regulatory compliance (3.32), technical expertise (3.30), device standardization issues (3.28), and insufficient technical knowledge (3.24). While all these challenges scored above the neutral threshold of 3.0, the findings notably reveal that organizational and system-related obstacles pose greater concerns than those related to technical expertise.

b. To Determine the Relevancy of IoT Applications That are Suitable to FM Efficiency

Objective two is to determine the relevancy of IoT applications that are suitable to FM efficiency that develop into six constructs namely, (i) real-time monitoring, (ii) enhancing decision-making processes, (iii) resource allocation, (iv) predictive maintenance enabled, (v) utilizes data analytics and (vi) improving communication among teams.

Table 3.0: Mean Factors for Six Constructs of The Relevancy of IoT Applications That Are Suitable to FM Efficiency

Construct	Level of Relevant	Frequency	Percentages (%)	Mean
Real-time monitoring	Irrelevant	12	16.9	3.30
	Less Relevant	6	8.5	
	Neutral	19	26.8	
	Relevant	17	23.9	
	Most Relevant	17	23.9	
Enhancing decision-making processes	Irrelevant	8	11.3	3.38
	Less Relevant	9	12.7	
	Neutral	17	23.9	
	Relevant	22	31.0	
	Most Relevant	15	21.1	
Resource allocation	Irrelevant	6	8.5	3.73
	Less Relevant	3	4.2	
	Neutral	14	19.7	
	Relevant	29	40	
	Most Relevant	19	26..88	
Predictive maintenance enabled	Irrelevant	8	11.32	3.35
	Less Relevant	10	14.1	
	Neutral	16	22.5	
	Relevant	23	32.4	
	Most Relevant	14	19.7	
Utilizes data analytics	Irrelevant	11	15.5	3.38
	Less Relevant	7	9.9	
	Neutral	13	18.3	
	Relevant	24	33.8	
	Most Relevant	16	22.5	
Improving communication among teams	Irrelevant	10	14.1	3.18
	Less Relevant	11	15.5	
	Neutral	21	29.6	
	Relevant	14	19.7	
	Most Relevant	15	21.1	

Table 3.0 presents the mean factor. The highest mean factor is system resource allocation (mean score 3.73), enhancing decision-making processes (3.38), and utilizing data analytics (3.38). At a moderate level of concern, facilities managers grapple with IoT system predictive maintenance enabled (3.35), real-time monitoring (3.30), and improving communication among teams (3.18). Nevertheless, the improved communication among teams generated a divided response, suggesting that further investigation is necessary to determine its efficacy in FM contexts. Industry professionals' perceptions are reflected in a variety of constructs that emphasize the relevance of IoT applications that are appropriate for improving FM efficiency. Overall, these results demonstrate a robust recognition of the diverse IoT applications and their potential to improve the efficiency of FM.

CONCLUSION

The integration of IoT into FM has become a crucial approach for improving operational efficiency and sustainability. This research seeks to ascertain the capabilities of IoT technology in forecasting equipment breakdowns and proactively scheduling maintenance, therefore reducing downtime and prolonging asset lifespans. The findings reveal that although IoT technologies like real-time monitoring and predictive maintenance provide significant advantages, problems like data security issues, elevated initial investment costs, and integration complexities must be resolved for effective application. This study highlights the transformational capacity of IoT in enhancing FM processes and advancing sustainability objectives.

The research findings underscore the substantial importance of IoT solutions in improving operational efficiency within facilities management. The study highlighted major IoT applications that help FM efficiency, notably in areas such as resource allocation, predictive maintenance, and real-time monitoring, after conducting a thorough examination of answers from 71 facility managers. Of the respondents, 32.4% agreed that predictive maintenance is important, while a noteworthy 40% said that resource allocation is a crucial application. The study indicated that improving decision-making processes using data analytics is seen as somewhat advantageous, with a mean score reflecting substantial endorsement of its contribution to optimizing FM operations. Despite skepticism about the efficacy of enhancing team communication through IoT, the findings emphasize a strong recognition of IoT's capacity to revolutionize FM practices. This research underscores the significance of IoT in enhancing efficiency and functions as a fundamental reference for further investigation into its applications and effects in the FM industry.

The study revealed considerable potential for IoT applications, including real-time monitoring, predictive maintenance, and data analytics, to enhance FM processes. It also underscored significant challenges, such as difficulties in system integration, concerns regarding data security, and substantial initial investment costs that need to be addressed for successful implementation. The findings confirm the significance of IoT in enhancing FM efficiency, especially in resource allocation and energy management, facilitating data-driven decision-making and proactive maintenance strategies that minimize downtime and operational costs. Moreover, the IoT significantly contributes to sustainability through the enhancement of energy efficiency and the minimization of waste. The study highlights the significant influence of IoT on FM practices and emphasizes the need for additional research into cost-effective solutions for smaller facilities, interoperability challenges, and improved cybersecurity measures to fully harness IoT's potential in transforming FM and advancing broader environmental objectives.

ACKNOWLEDGMENT

The main author would like to express her gratitude to Quantity Surveying Department of UiTM Perak branch, especially the supervisor for funding this publication.

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THE INFLUENCE OF DIGITALIZATION IN THE TRANSFORMATION OF THE REAL ESTATE AGENCIES

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ABSTRACT

The real estate industry in Malaysia is undergoing a major transformation with the rise of digital platforms like PropertyGuru, iProperty, and social media, which are making it more convenient and faster to sell property. While these advances help real estate agencies reach connect customers and streamline operations, there are challenges faced such as illegal brokers, online fraud, and time constraints in face-to-face sales, buying, renting, leasing. This study aims to identify the most commonly used websites, social media platforms, and applications for selling, purchasing, renting, and other real estate-related transactions in the real estate market. this research employs a systematic literature review approach, this research relies on secondary data from peer-reviewed journals, statistical reports, and industry publications. The study explores how these agents use digital platforms to market properties and carry out transactions. This finding will give recommendations to allow people to look for property with the objective of buying, renting, leasing legally without any element of fraud and in time to facilitate this business, as well as for professionals in real estate agent businesses to fully adopt digital tools while managing industry threats. Lastly, this study seeks to bridge the gap between traditional real estate practices and modern technology to ensure the industry remains competitive and sustainable in the digital age. Findings reveal that Facebook and PropertyGuru are the most preferred platforms among real estate agents due to their wide reach, trusted features, and ability to attract clients of all age groups.

Keywords: (Digitalization, Real Estate Agencies, Online Platforms, Marketing Strategies, Klang Valley)

I. INTRODUCTION

1.1 Research Background

The Internet has revolutionized industries around the world, including the real estate sector. As a global medium that connects millions of people, it has become a vital tool in digital transformation. Businesses and consumers alike rely on the internet for communication, marketing and commerce (A G Siti Munirah & H Ezdihar, 2022). In particular, digitalization has reshaped the way real estate agencies operate, significantly improving their ability to market and manage properties.

Digital tools and online platforms have redefined real estate transactions, enabling real estate agencies to expand their reach and improve service efficiency. Platforms such as PropertyGuru and iProperty have become key platforms in the Malaysian real estate market, enabling real estate agencies to showcase properties with high-quality visuals and detailed, legitimate information. This transformation is in line with a broader trend in digital marketing, where businesses of all sizes are using social media tools such as Facebook, Twitter and YouTube to increase brand awareness and customer engagement (AG Siti Munirah & H Ezdihar, 2022). The role of social media in real estate marketing is increasingly prominent, with agencies leveraging these platforms to share listings, conduct live virtual tours, and interact with potential buyers.

The growing reliance on digital platforms is also supported by the high internet penetration in Malaysia. According to Export.gov (2020), 25 million out of 32.25 million Malaysians are active users of social media, with over 40.24 million mobile subscriptions and 24 million users accessing social media via mobile devices. This widespread

connectivity highlights the need for real estate agencies to effectively adapt to digital marketing strategies. The ability to provide seamless online property tours has also enabled agents to cater to the needs of foreign home buyers and complete transactions across different regions (Khoo, 2020). This shift is significant as it increases accessibility, reduces transaction times and fosters a more efficient property search process.

To remain competitive, real estate agents must continue to evolve their digital strategies. Integrating advanced marketing tools, such as targeted advertising and immersive virtual experiences, has become a key differentiator and competitive advantage in the industry. It is essential for agencies to adapt and adopt these technologies to maintain a competitive edge in the rapidly digitizing real estate landscape (Tan Jia Ying, 2022).

This study aims to explore what online platforms are commonly used by Malaysian real estate agencies, focusing on the use of online platforms and social media strategies. By analyzing how agencies integrate these tools, this research provides insights into how people search for properties legitimately and how businesses can leverage technology for greater marketing success and customer satisfaction.

1.2 Problem Statement

The Malaysian real estate industry is undergoing a rapid digital transformation, bringing both opportunities and challenges. While online platforms and digital tools offer convenience and accessibility, they also introduce risks that impact agents, buyers and industry stakeholders.

The growth of digital platforms has made it easier for illegal brokers to operate in Malaysia without proper licenses. These unregistered agents exploit online platforms to attract clients while circumventing regulations. According to Zarita et al. (2024), the anonymity provided by digital tools makes it difficult to distinguish legitimate agents from fraudulent agents or known brokers. Many individuals, especially in rural areas, may lack the knowledge to verify the qualifications of agents, leading to financial losses and unethical practices. Weak regulatory enforcement exacerbates this issue, making digital verification and a stricter legal framework necessary (Ahmad et al., 2024).

As digital transactions increase so will the risk of online fraud. Brokers pose as legitimate agents, post fake property listings, and trick buyers into making fake payments. Reports show that fraudsters typically use social media and messaging apps such as WhatsApp and Telegram to lure victims. New Straight Times (2024) reported cases of fraudsters using real estate agents' names and images to commit fraud. In addition, excessive sharing of personal information online increases exposure to digital fraud, highlighting the need for stronger cybersecurity measures. For example, platforms such as iProperty and PropertyGuru have implemented stricter listing verification to protect consumers.

Traditional real estate transactions in Malaysia are often time-consuming and require multiple physical meetings and excessive paperwork. This process is impractical for busy professionals and individuals looking for properties in locations far from the client. Digital solutions such as virtual reality (VR) tours, e-signatures and online payment platforms offer more efficient alternatives. However, adoption rates vary, with urban consumers embracing digital tools more readily than rural clients and older generations. Real estate firms must ensure that digital solutions are user-friendly and accessible to all demographics. Based on the identified research gaps and challenges, this study sought to answer the following key questions: what are the most widely used online platforms, social media channels, and mobile applications for buying, selling and renting properties in the Malaysian real estate industry? Thus, this study aims to examine the most used websites, social media platforms, and mobile applications by real estate agencies for property transactions in Malaysia.

II. LITERATURE REVIEW

2.1 The Definition of Estate agent

Real estate agents are licensed professionals who facilitate the purchase, sale, and rental of real estate. Their roles include marketing properties, negotiating offers, and ensuring a smooth transaction for clients (Nur Shafiqah Abdul Manaf & Hairul Nizam Mansor, 2018). Agents earn commissions when transactions are successful and must stay up to date on market trends, property values, and regulations to provide accurate advice.

For sellers, real estate agents assist in pricing properties, positioning homes, and promoting listings through brochures and online platforms. For buyers, they help identify suitable properties, arrange viewings, and negotiate prices to ensure a fair deal. In addition, real estate agents handle legal paperwork and make complex property transactions more efficient.

A solid understanding of the real estate market allows agents to guide clients effectively, minimize risk, and ensure informed decision-making. Their expertise is essential in navigating the evolving real estate landscape and ensuring a smooth process for all parties involved. In Malaysia, under the Valuers, Appraisers, and Estate Agents Act 1981 (Act 242), there are three main categories of real estate professionals:

a. Registered Estate Agent (REA)
   Fully licensed professionals who have passed the Board of Valuers, Appraisers, Estate Agents, and Property Managers (BOVAEP) examinations and completed practical training. They can legally operate real estate firms.

b. Probationary Estate Agent (PEA)
   Individuals undergo a two-year practical training program under an REA before qualifying for the final professional exam.

c. Registered Estate Negotiator (REN)
   Salespersons working under a REA, requiring certification from BOVAEP but without the authority to operate independently (Ting Kien Hwa, & Zarita Ahmad@Baharum, 2024)

2.2 Definition of Digitalization in Real Estate

Digitalization involves the integration of digital technologies into business operations, reshaping traditional processes and increasing efficiency. Unlike digitalization, which simply converts analog data into digital form, digitalization extends to the use of digital tools for innovation and better customer interaction (Naeem et al., 2023).

The real estate industry has benefited significantly from digitalization, changing the way real estate is marketed, sold and managed. Automated processes reduce paperwork, speed up transactions, and enable real-time communication between stakeholders (Naeem et al., 2023). For example, digital platforms can cut transaction times in half compared to conventional methods (Volkova & Koroleva, 2022). Digitalization includes online platforms such as websites, applications, social media and online communication, including business transactions.

In addition, digitalization promotes transparency and accessibility. Online platforms allow buyers, sellers and agents to easily access market data, improving the decision-making process. Accordingly, Dr. Gita Rani Sahu (2024), developers also use analytical tools to understand market trends and adjust marketing strategies by making the industry more efficient and customer centric.

2.3 Social Media on Real Estate

Social media has revolutionized the way real estate agents connect with clients, market properties, and build their professional presence. Compared to traditional advertising, platforms like Facebook, Instagram, and TikTok offer a cost-effective and highly interactive way to engage with potential buyers and sellers (A G Siti Munirah & H Ezdihar, 2022). These platforms enable agents to showcase properties through visually appealing photos, videos, and virtual tours, making listings more accessible and attractive.

With the widespread use of social media across all age groups teenagers, adults, and even older individuals spend a significant portion of their day browsing these platforms or social media. This makes social media an effective tool for property hunting, as users can explore homes anytime, anywhere, without the need for physical visits. By simply viewing images or videos, potential buyers can get a sense of the property before scheduling an in-person viewing. Many real estate firms integrate social media with digital marketing and e-commerce tools to enhance customer engagement (AG Siti Munirah & H Ezdihar, 2022). With effective use of this platform, agents can build credibility, build trust with customers and make more sales, hence transforming the way real estate business is done nowadays.

2.4 Facebook

Facebook has become one of the most influential social media platforms worldwide (Cornelius JJ Wessels & Boitumelo M Diale, 2017). Since its launch in 2004, it has evolved from a simple social networking site into a powerful tool for marketing, communication, and business engagement. With over 3.07 billion monthly active users, Facebook provides an extensive audience reach, making it an essential platform for real estate agents to market properties and connect with potential buyers (Semrush, 2025).

One of Facebook's strengths is its diverse advertising options. Agents can use Facebook Pages to create professional profiles, showcase property listings, and interact with clients. Additionally, Facebook Groups allow agents to engage with niche communities, such as property buyers, investors, or renters, fostering direct and personalized communication. The platform's targeted advertising features enable real estate professionals to reach specific demographics based on location, interests, and online behavior.

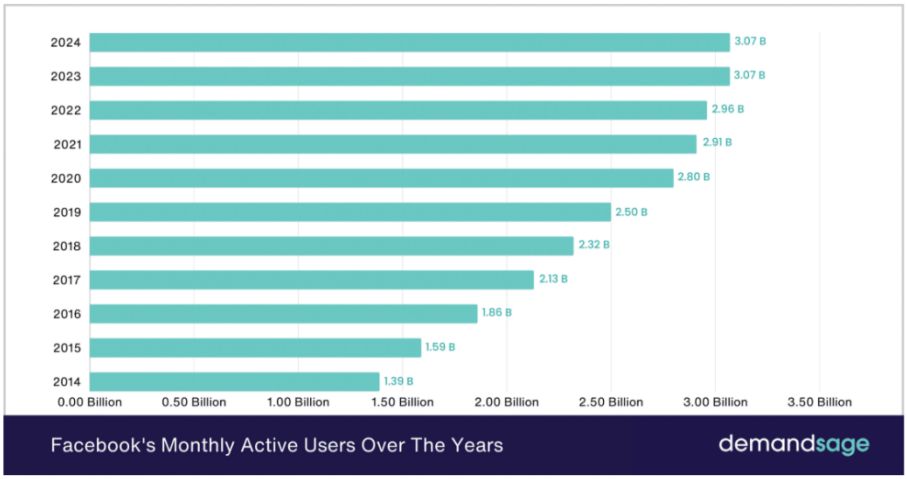


Figure 3.0 Facebook's Monthly Active Users Over the Years (Source: Statista 2025)

2.5 PropertyGuru

PropertyGuru is one of Malaysia's leading online property marketplaces providing a convenient platform for buyers, sellers and investors to explore property opportunities. The portal allows users to search for properties for sale, rent or investment, making it easier to connect with real estate agents and developers. According to PropertyGuru Malaysia, with over 330,000 residential and commercial property listings, PropertyGuru.com.my is the platform of choice for those looking for a home or business space in Malaysia. PropertyGuru is unique in that it features user-friendly search tools and filtering options, allowing buyers to narrow down their choices based on location, price range, property type and other options. The platform also provides market insights, property trends and financial tools to help users make informed decisions.

Importantly, only registered estate agents are allowed to advertise their listings on PropertyGuru. This ensures that all property transactions on the platform are conducted by legitimate professionals, thus making it a safer and more reliable choice for buyers and renters.For real estate agents, PropertyGuru serves as a powerful marketing tool, allowing them to reach a large audience. With digital marketing features such as high-quality property images and a directory of authorized agents, PropertyGuru enhances the buying and selling experience, making property transactions smoother and more transparent.

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2.6 iProperty

iProperty Malaysia, founded in 2007, is a leading digital property platform that simplifies property searches for buyers, renters and investors. It acts as a bridge between property seekers, real estate agents and developers, making the process of finding a home or investment property more transparent and efficient. The platform provides detailed property listings, including images, prices, locations and descriptions, helping users make informed decisions without the hassle of traditional property hunting.

In 2019, iProperty.com.my was acquired by PropertyGuru, further strengthening its position in the Southeast

Asian property market. The acquisition enhanced the platform's technology, data insights, and user experience, making it more effective for both buyers and property professionals.

From the data of Semrush Traffic Analytics tool, currently the most highest visited website in Malaysia for real estate searching is PropertyGuru followed by iProperty as recorded in February 2025.

2.7 Instagram

Instagram is a popular social media platform that allows users to share photos and videos instantly. Launched as a free app for iPhone and Android, Instagram allows people to upload images or videos (up to 1 hour long) and share them with their followers or selected friends. Users can also like, comment, and engage with content, making it a highly interactive platform. With an estimated 1.44 billion users by 2025, Instagram continues to be one of the most influential social media sites worldwide (Statista, 2025).

For real estate agents, Instagram serves as a powerful marketing tool. The visual nature of the platform allows agents to showcase properties through high-quality images, virtual tours, and short video clips. Features like Instagram Stories, Reels, and IGTV provide engaging ways to showcase listings, share market insights, and connect with potential buyers.

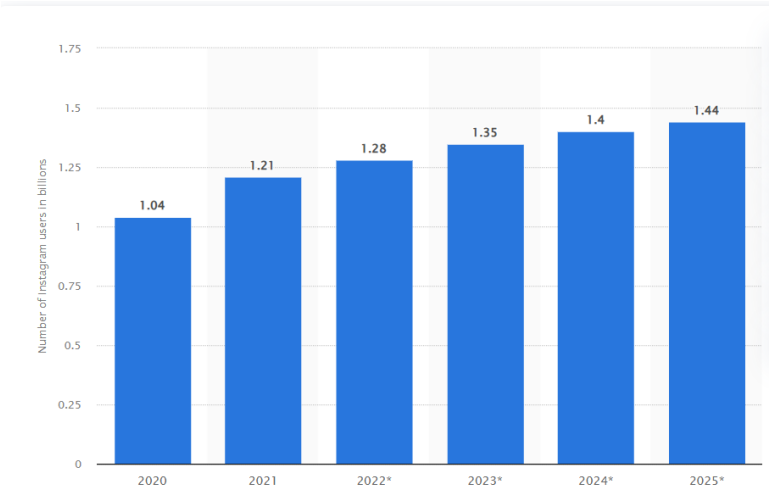


Figure 4 Number of Instagram users worldwide from 2020 to 2025 (Source: Statista 2025)

2.8 Traditional Real Estate Agency Practices

Before digital platforms became popular, real estate agents relied heavily on traditional advertising methods such as printed brochures, catalogues, flyers, and newspaper advertisements. According to the Malaysian Estate Agency Standards (MEAS), all property advertisements must be accurate, factual, and not misleading. Agents were also required to include full registration details in every advertisement to maintain transparency and professionalism. Flyers and print ads needed to show clear information about the property and the agent to ensure transparency. As highlighted Nur Syahira Alia Misran & Khadijah Md Ariffin (2021), printed promotional tools were commonly used in marketing commercial properties such as brochures and newspaper ads were widely used in commercial property marketing. Back then, agents were the ones actively seeking clients through these printed materials. However, with the evolution of digital technology, this has changed with clients now seeking agents through online platforms.

III. RESEARCH METHODOLOGY

This study uses a literature review approach, using secondary data from peer-reviewed journals, statistical reports, and industry publications. The research specifically aims to examine the most commonly used websites, social media platforms, and mobile applications by real estate agencies in Malaysia for buying, selling, and renting properties.

The study systematically examines the most common digital platforms used by real estate agencies for real estate transactions in Malaysia. Key areas of investigation include digital marketing strategies, online property listing

effectiveness, and consumer engagement trends. By reviewing existing studies, this research identifies the impact of digitalization on real estate transactions, focusing on factors such as efficiency, accessibility, and consumer adoption rates.

In addition, findings from the authors (Siti Munirah and Ezdihar, 2022), which analyzed the frequency and percentage of preferred online platforms used in real estate marketing strategies. By assessing these trends, the research provides insights into how digital tools shape industry practices and influence consumer behavior in the Malaysian real estate sector.

IV. RESEARCH RESULTS

Based on the research findings, the frequency and percentage of preferred digital platforms influencing real estate marketing strategies are summarized in Table 1. The analysis of these platforms provides valuable insights for real estate agents to refine their online marketing strategies and effectively reach potential buyers.

Table 2- Preferred platforms for real estate marketing in Malaysia

Authors/website	Most Popular Platform for Real Estate in Malaysia	Respondents/ review
Semrush.com (as February 2025)	1. PropertyGuru 2. iProperty 3. edgeprop	Website traffic tools
Murni, Mohd Aini and Alias, 2024	1. Mobile instant messaging 2. Social media 3. Real Estate Agent's website	Estate agency and valuation practitioners
Rehda Institute, 2022	1. Facebook 2. Instagram 3. Youtube	Real Estate Developers
Siti Munirah and Ezdihar, 2022	1. Facebook 2. PropertyGuru 3. iProperty	Real estate agents
Azlie and Hamzah, 2020	1. website 2. application 3. social media 4. google	Real estate company

The result shows the most preferred digital platforms for real estate marketing in Malaysia, as summarized in Table 1. These insights provide real estate agents with valuable information to refine their online marketing strategies and effectively connect with potential buyers.

1. Semrush.com, 2025
   According to website traffic analysis, PropertyGuru leads with (2,994,891 visits), followed by iProperty (1,669,728 visits) and EdgeProp.com (708,327 visits). This data indicates that property listing websites remain the primary choice for online real estate searches.

2. (Murni, Mohd Aini & Alias, 2024)
   Research among registered real estate agents highlighted the widespread use of mobile instant messaging and social media as important ICT tools, with both achieving a high Relative Importance Index of 0.925. In addition, the real estate agency website is another important digital tool for real estate marketing.

3. (Rehda Institute, 2022)
   A survey of real estate developers revealed that Facebook (75 respondents) was the most widely used platform, followed by Instagram (60 respondents) and YouTube (40 respondents). This shows that visual and interactive platforms are key to promoting real estate projects. Facebook came out on top because it is a platform with a large user base.

4. (Siti Munirah & Ezdihar, 2022)
   A study on marketing strategies in Johor Bahru found that Facebook (46.8%) was the most preferred platform,

closely followed by PropertyGuru (43.5%). Meanwhile, iProperty (5.3%) was identified as another important option for property advertising.

5. (Azlie & Hamzah, 2020)
   A survey of property companies found that websites were the most commonly used platform, followed by mobile apps (82%), social media (80%) and Google (66%). This shows that businesses prefer structured digital platforms for property marketing.

V. DISCUSSION

The research findings from 5 sources reveal that Facebook, PropertyGuru, and websites as the most preferred platforms for real estate marketing in Malaysia. Facebook is widely used, with 47% of real estate agents in Johor Bahru relying on it (Siti Munirah & Ezdihar, 2022) and Rehda Institute (2022) confirming its popularity among developers. Facebook has a diverse user base, from young to elderly users. It was found that Facebook is a commonly used platform because many people use it, and some even rely on it for buying and renting properties.

Besides, PropertyGuru, dedicated exclusively to real estate, attracts nearly 3 million visits (Semrush.com, 2025) and is preferred by 43.5% of agents (Siti Munirah & Ezdihar, 2022). It provides a trusted space where only registered agents can advertise, thus ensuring a safer and more professional environment for buyers and sellers.

Furthermore, websites, including PropertyGuru, iProperty, and other agency websites, are important for real estate marketing (Azlie & Hamzah, 2020). They provide credibility, structured property listings, and direct client engagement which facilitates transactions for buying, selling, renting and leasing. Going forward, agents should continue to explore innovative digital marketing techniques to remain competitive in the evolving property industry.

CONCLUSION

In conclusion, real estate agents prioritize platforms with the highest audience reach to maximize their profits and chances of closing deals. The more exposure their property listings receive, the more likely they are to attract buyers or tenants. Among the various digital platforms available, Facebook is the most commonly used for social media marketing, while PropertyGuru stands out as the leading website for property listings.

Both platforms serve as key points of contact between buyers, sellers and agents to streamline real estate transactions, whether to buy, sell or rent. PropertyGuru is particularly effective due to its extensive property listings at a range of prices offered at the right market value, detailed information for each property and a user-friendly interface that makes it easy for buyers and tenants to make informed decisions.

The digitization of real estate has changed the way properties are marketed and searched for. Instead of visiting multiple locations, buyers and tenants can now browse listings, compare prices and access property details online. As digital tools continue to evolve, estate agents need to leverage platforms like Facebook and PropertyGuru is essential for real estate professionals to remain competitive and successful in the modern real estate market.

ACKNOWLEDGMENT

The main author would like to express his gratitude to UiTM Perak branch, especially the Department of Built Environment and Tecchnology for funding this publication.

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THE NATURAL DAYLIGHTING FOR ENERGY EFFICIENCY SIMULATION AT MALAYSIA EXHIBITION SPACE: A CONCEPTUAL PARADIGM

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ABSTRACT

The integration of natural daylight in the design and operation of exhibition spaces offers significant potential for reducing energy consumption while enhancing the overall visitor experience. This conceptual paper investigates the role of natural daylighting as a sustainable design strategy in exhibition spaces in Malaysia. The study aims to evaluate current awareness and implementation of daylighting practices among architects, facility managers, and users, identify best practices for optimizing natural light usage, and assess its impact on energy efficiency and visitor comfort. A mixed-methods approach is proposed, utilizing observational analysis and simulation process by applying DIALUX lighting software Simulation to gather comprehensive data on existing daylighting strategies in exhibition spaces. Observational methods will document the effectiveness of daylighting systems and their influence on energy performance, while the literature review will contextualize findings within the broader framework of sustainable architectural practices. The anticipated outcomes of this study include actionable insights for improving daylighting strategies, practical recommendations for architects and exhibition organizers, and an enhanced understanding of the balance between sustainability and functionality in art exhibition design. Ultimately, this research aims to contribute to advancing energy-efficient practices in Malaysian's cultural infrastructure, promoting a sustainable architectural approach that aligns with ecological and cultural objectives

Keywords: Natural daylighting; Energy efficiency; Sustainability, Exhibition space

I. INTRODUCTION

Energy efficiency has been widely recognized as main consideration in reducing environmental impacts and enhancing sustainability, particularly in buildings designed for public use. Among the various strategies to improve energy efficiency, optimizing natural daylight has gained significant attention due to its potential to reduce reliance on artificial lighting while improving the occupants' well-being. Art exhibition centers, in particular, require a delicate balance between utilizing natural daylight and protecting sensitive art pieces from harmful light exposure.

Art exhibition centers in Malaysia have seen a rise in interest as part of the state's growing cultural identity and tourism development. According to Hurlbert et al. (2020, the architectural designs of art spaces are increasingly incorporating sustainable practices, which include the use of natural daylight to minimize energy consumption. Furthermore, daylight is not only an energy-saving element but also enhances the visual experience of the art being displayed, as noted by Shamri et al., (2022) whom emphasized that controlled daylighting can elevate the aesthetics of art exhibitions while reducing carbon emissions.

Malaysia’s tropical weather conditions dominate the climate, harnessing natural daylight poses challenges such as managing heat gain and glare. Recent studies have shown that integrating advanced daylight control systems, such as smart shading and reflective materials, can mitigate these issues. buildings in tropical regions, including art centers, could achieve up to 40% reduction in lighting energy usage with optimized daylighting systems,

further supporting the importance of natural light in sustainable building design (Razak et al., 2023).

At the same time, careful attention must be paid to the preservation of artworks. Overexposure to daylight can lead to fading and deterioration of sensitive materials. According to Ismail et al. (2024), modern exhibition spaces have begun utilizing specialized glazing and UV filters to ensure that the benefits of daylight are maximized without compromising the integrity of the art displayed. In summary, energy efficiency through natural daylight in exhibition spaces represents an innovative and environmentally responsible approach to design application. Thus, this conceptual paper investigates the role of natural daylighting as a sustainable design strategy in exhibition spaces in Malaysia. The study aims to (i) evaluate lighting practices among architects, facility managers, and users, (ii) identify best practices for optimizing natural light usage, and assess its impact on energy efficiency of art exhibition space.

II. LITERATURE REVIEW

The integration of natural daylighting in buildings has gained significant attention as a sustainable architectural strategy. Art exhibition centers, particularly in tropical regions in Malaysia, present both challenges and opportunities in effectively utilizing daylight. While daylighting can enhance energy efficiency, it must also ensure the preservation of sensitive artwork. To address these complexities, this literature review explores strategies for optimizing daylight, incorporating energy efficiency principles, regulatory guidelines, and technological advancements.

Natural Daylighting and Energy Efficiency

Daylighting has become a critical component of energy-efficient building design. According to MS 1525:2019 (Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings) [5], optimizing daylight penetration can significantly reduce energy consumption. Escobar (2024) highlights that high-transmittance glazing improves indoor lighting while maintaining the natural spectrum, enhancing both efficiency and occupant well-being. Razak et al., (2023), further emphasizes that skylight design can optimize daylight penetration, reducing reliance on artificial lighting while maintaining aesthetic appeal.

Table 1.0 summarises the initiative design and application of natural daylighting at exhibition space. Research by Razak et al., (2023), demonstrates that daylighting strategies tailored for tropical climates can reduce lighting energy consumption by up to 40%. Aderonmu et al., (2019) explores the use of phase change material (PCM) glazing, which enhances thermal stability and minimizes temperature fluctuations, improving energy performance. Lee et al., (2020) investigates daylight-concentrating louvers. Combined with LED dimming systems, showing substantial reductions in lighting energy consumption. These advancements highlight the growing potential of daylighting technologies in achieving sustainable, climate-responsive energy efficiency.

Table 1.0 The initiative design and application of natural daylighting at exhibition space

	Authors	Case study	Application	Findings
1	Dalipi, 2021[a]	● Exhibition space, museum	**Geometric holes light** to enter by illuminating the halls and spaces of the museum's dome and wall	Visitors' paths and controlling the natural light temperature without blocking natural light
2	Kim, 2014[a]	Mimesis art museum space	**Enhance external courtyards and the internal patios** Proposed **skylights and windows.** Therefore, more considerations to control the natural light are needed	**Control the natural light** are needed to secure stable lighting environment. Attentions concerning the visitors' circulation, the display of exhibits and the lighting control
3	Moreira, 2021[a,b]	Exhibition Space	**Combining artificial and controlled natural lighting** solutions for museums proves to be a successful approach to improve the quality of the spaces Application of **LED lights at sensitive space**	**Identifying the different museum areas** and facilitating the orientation within the center and sensitivity of artifact.
4	Chidi & Daminabo, 2022[a,c]	● Exhibition space, museum	● **Top-lighting opening in the interior ceiling** ● Side and top lighting apertures, all of which are indirect; the windows face the central atrium, which is covered by a glass canopy, and the top-light openings,	● Only consideration on benefits and considerations of daylight introduction in museum galleries, and types of daylight openings and connection to the outdoors
5	Muñoz-González, 2021[b]	Domestic space in historic centers	Strategies consist mainly in the replacement of incandescent or fluorescent lamps with **LED lamps**	Improve people's well-being while reducing energy expenditure on lighting, this article presents a quantitative approach to improving the levels of natural lighting in residential heritage buildings located in historic centers
6	Sholanke & Oyeyipo,	● Museum exhibition	● The analysis showed that the use of **domes, clerestory windows, atriums, light tubes and**	● Explores various strategies and techniques on how daylighting can be achieved in the

	2023[a,c]	space	**anti-solar glass/windows were considered to be most adequate daylighting features** for daylighting designs and energy efficiency optimization	museum spaces
7	Marzouk *et al*., 2020[a,c]	● Historical building	● The parametric design provides multiple design options for the **skylight** which target performance criteria for natural daylight	● Implemented a parametric configuration approach to **redesign the skylight**.
8	Aderonmu *et al*., 2019[a,c]	● Museum space	● Application of **domes, clerestory windows, atriums, light tubes and anti-solar glass/windows** were considered to be most adequate daylighting features sufficient for daylighting designs and energy efficiency optimization	● showed that there are parametricenergy design indices in the existing architectural designs that are applicable in forms, spaces, materials, techniques, installation and strategies to museums in the tropical climatic region
9	Shahparnia *et al.,* 2020[a,b,c]	● Museum exhibition space	● Natural lighting systems widely used in museums shows that the **photovoltaic** systems are the most appropriate ones for natural lighting in the museum, followed by **light shield, light pipe, and light shelf**	● visual indicators of ergonomic lighting based on the high-quality natural light provides the desirable lighting in the museums. ● Combining photovoltaic shades with light shields can optimally distribute the light while controlling glare, luminance, shading, and contrast in museums of artworks
10	Xu *et al.,* 2021[c]	● Museum Exhibition space-China	● The **intelligent motion capture lighting** system designed apply, ensure the exhibition experience and reduce the unnecessary exposure of museum exhibits. ● Apply natural lighting when the visitors unattended	● Motion capture has great potential in game animation, film and television animation, virtual image, and other fields. However, in the current commonly used motion capture schemes, the cost of equipment is very high, and the implementation site is limited

a-Design elements b-lighting energy saving technology c-materials savvy

Table 1 indicates eight out of ten researchers find the case studies are favoured to utilised the design elements to obtain the energy efficiency of natural lighting at museum exhibition space. These designs including enhance external courtyards and the internal patios skylights and windows applications, solar tube hole light at dome and wall. Layout and location of exhibition space to be in the consideration too.

Standards and benchmark of lighting levels for exhibition centers

Ensuring appropriate lighting levels in exhibition centers is essential for both art preservation and visitor experience. Various international and national standards provide benchmarks for maintaining optimal illuminance levels, balancing visibility, energy efficiency, and artwork protection. According to the Illuminating Engineering Society (IES) and the CIE (2004) (International Commission on Illumination), the recommended lighting levels in art exhibition spaces vary based on the sensitivity of artworks:

- Highly sensitive artworks (e.g., watercolors, textiles): 50 lux (maximum)
- Moderately sensitive artworks (e.g., oil paintings, wood sculptures): 150– 200 lux
- Less sensitive materials (e.g., stone, metal sculptures): 300 lux and above

In Malaysia, the MS 1525:2019 Code of Practice on Energy Efficiency and Renewable Energy for Non-Residential Buildings provides guidelines on energy efficient lighting in buildings, including exhibition spaces. The standard recommends efficient lighting designs incorporating daylight harvesting, automatic controls, and LED technology to reduce energy consumption while ensuring compliance with visual comfort requirements. (Table 2)

A few general of energy efficiency for lighting practise as lighting must provide suitable visual environment within a particular space such as sufficient and suitable lighting for performance or range of tasks and provision of desired appearance and maintained illuminance level to general building area.

Additionally, the UNESCO Conservation Guidelines emphasize that prolonged exposure to direct sunlight and UV radiation can cause fading and degradation of artworks. To mitigate these risks, exhibition centers should incorporate UV filtering glazing, controlled daylighting strategies, and dynamic shading systems to regulate natural light exposure. By aligning with these standards and benchmarks, exhibition centers in Malaysia can achieve optimal lighting conditions, ensuring energy efficiency, visual comfort, and artwork protection.

Challenges in Daylighting for Museum and Art Exhibition Space

While daylighting provides energy-saving benefits, its application in exhibition space remains challenging. Excessive sunlight exposure can cause artwork degradation, as UV rays and uncontrolled light levels contribute to fading and deterioration Dalipi (2021). To address these risks, daylighting strategies must comply with international museum lighting standards, such as the CIE 157:2004 Guide for Lighting Museums and Galleries

(CIE, 2004), which recommends strict UV filtration and controlled illuminance levels.

Furthermore, tropical climates in Malaysia lose heat gain and glare issues, increasing cooling loads and reducing daylighting efficiency. Kim et al. (2014) advocate for smart glazing, automated shading, and reflective materials to balance daylighting with artwork protection. Zhang, (2022) introduces algorithm based shading systems, which dynamically adjust daylight penetration, achieving a balance between natural light, thermal comfort, and energy savings.

Beyond energy efficiency, daylighting enhances the visual and experiential quality of exhibition spaces. Xu et al., (2021) states that integrated daylight control systems improve visual comfort, ensuring optimal illumination without compromising art preservation. Al-Obaidi et al. (2023) emphasizes daylight's role as a design element, shaping spatial perception and influencing visitor experience and emotional well-being. Additionally, daylighting must be aligned with sustainability goals set by Malaysia's Green Building Index (GBI), which encourages passive daylighting strategies and efficient energy use in public buildings. Implementing these strategies ensures that exhibition spaces in Malaysia can achieve an optimal balance between aesthetics, energy savings, and artwork preservation.

Sustainable Design and Application of Natural Daylighting to Obtain Energy Efficiency

The energy issue is more important in today's world because of a possible energy shortage in the future and also global warming. Since the Kyoto protocol signed in December 1997, the majority of governments around the world have committed themselves to reducing the emission of the greenhouse gases. Efficient use of energy has become a key issue for the most energy policies. Buildings are one of the most significant energy consumers. Due to that purposes, table 2 indicates the initiative design and application of exhibition space that has been applied by peer-researchers.The peer-reviews are summarised by the application and adaption of natural daylighting to achieve energy efficiency by three categories; (1) design of building elements, (2) lighting energy-saving technology and (3) materials used.

III. METHODOLOGY

A. The Case Studies

The research focuses on several exhibition spaces in Malaysia, chosen for their architectural diversity, historical significance, and management practices. Yet, due to simulation purposes to adapt the energy effency, Penang State Art Gallery located in George Town, Penang will be approach. It is due to the various content of arts, space available and the age.

B. Types Of Data Collection

This study employs a simulation-based approach to evaluate the effectiveness of natural daylighting strategies in exhibition spaces within Malaysian contexts. The simulation method enables precise analysis of daylight penetration, energy savings, and visual comfort, ensuring optimal lighting conditions for exhibitions while minimizing energy consumption. Advanced daylighting simulation software, such as Radiance and DIALux, will be used to model various scenarios and assess the impact of daylighting interventions. These tools allow for an accurate representation of natural light dynamics, taking into account variables such as solar angles, window placements, material reflectance, and climatic conditions.

I. To begin the simulation process, a digital model of a standard exhibition space will be developed using Building Information Modeling (BIM) software. This model will incorporate architectural elements, fenestration details, and interior finishes relevant to daylighting performance. Key parameters, including window-to-wall ratio, glazing types, shading devices, and room orientations, will be systematically varied to analyse their effects on illuminance levels. The primary goal is to identify configurations that optimize natural light distribution while mitigating issues like glare and excessive heat gain.
   Table 4.0 interprets the summary of the Simulation strategy for this study. The evaluation will be conducted based on established lighting standards such as the Malaysian Standard MS 1525:2019, which provides guidelines for energy efficiency and renewable energy applications in buildings. Additionally, international benchmarks, including the Illuminating Engineering Society (IES) and the CIE (2004) (International Commission on Illumination), will be referenced to ensure that simulated lighting levels align with best practices for exhibition environments. The simulation outputs will include spatial illuminance maps, daylight autonomy analysis, and energy consumption comparisons between artificial and natural lighting scenarios.
II. A comparative analysis will be performed by simulating different daylighting strategies, such as the integration of skylights, light shelves, automated shading systems, and high-performance glazing. Each

strategy will be assessed in terms of its potential to reduce reliance on artificial lighting while maintaining visual comfort for visitors and protecting artworks from excessive exposure. Results from the simulations will provide quantitative insights into the percentage of energy savings achieved under each scenario.

III. The findings from the simulations will be synthesized into a decision-support framework for architects and exhibition designers. A set of practical recommendations will be derived, offering guidance on effective daylighting solutions tailored to tropical climates. The integration of simulation-based methodologies ensures that the proposed strategies are data-driven, adaptable, and aligned with sustainability objectives, ultimately contributing to the advancement of energy-efficient exhibition spaces in Malaysia.

Table 4.0 Summary of the Simulation Strategy for this study.

PARAMETER	DESCRIPTION
Software Used	Radiance, DIALux, BIM modeling
Variables Analyzed	Window-to-wall ratio, glazing type, shading devices
Key Metrics	Illuminance levels, daylight autonomy, energy savings
Standards Reference	MS 1525:2019, IES, CIE
Output Analysis	Spatial illuminance maps, energy consumption reduction

IV. To propose the option of energy efficiency. In this research, solar tube is proposed to replace the artificial lighting in common area of art exhibition space due to the daylight resource and the long term benefit on utilities and electrical usage and low maintenance. To propose the option of energy efficiency. In this research, solar tube is proposed to replace the artificial lighting in common area of art exhibition space due to the daylight resource and the long term benefit on utilities and electrical usage and low maintenance.

IV. RESULT

Malaysia building is abided by MS1525:2019 Code of Practice on Energy Efficiency and Renewable Energy for Non-Residential Buildings provides guidelines on energy efficient lighting in buildings, including exhibition spaces. It purposely to control the illuminance level at public space.

The literature review of The findings reveal that while natural daylighting is widely acknowledged as beneficial, many exhibition centers lack proper strategies for effective implementation. The results highlight several key observations. Firstly, many exhibition centers rely heavily on artificial lighting due to concerns about heat gain and glare. While natural daylighting reduces energy consumption, inadequate shading systems and poor window placements often result in overheating, leading to increased cooling costs. Table 1.0 indicate eight out of ten researchers find the case studies are favoured to utilised the design elements to obtain the energy efficiency of natural lighting at museum exhibition space. These designs including enhance external courtyards and the internal patios skylights and windows applications, solar tube hole light at dome and wall. Layout and location of exhibition space to be in the consideration too (Chidi et al., 2022)

Secondly, light distribution varies across exhibition spaces, affecting both artwork visibility and visitor comfort. Some areas receive excessive sunlight, which can cause fading or deterioration of sensitive artworks, while other areas remain underlit. Furthermore, the use of advanced daylighting controls, such as motion detection, smart shading systems and UV-filtering glass, remains limited in most exhibition centers.

Daylighting simulations confirmed that strategic placement of skylights, light shelves, and reflective surfaces can significantly improve light uniformity while minimizing heat gain (Dalipi, 2021) Optimized architectural design incorporating these elements can enhance sustainability without compromising artwork preservation.

Overall, the results emphasize the need for tailored daylighting strategies such as solar tube that consider climate specific challenges. Practical solutions such as improved shading devices, optimized window orientations, and automated daylighting controls are recommended to maximize energy efficiency and enhance visitor experience

CONCLUSION

In conclusion, Natural daylighting has immense potential to enhance energy efficiency and visitor experience in exhibition centers. However, its successful implementation requires a balanced approach that aligns with regulatory standards such as MS1525:2019, CIE 157:2004, and GBI guidelines. Advances in smart daylighting

technologies, such as automated shading and UV filtration, provide promising solutions to climate-specific challenges in regions like Malaysia. By integrating these strategies, the designers can create sustainable, visually appealing exhibition spaces that honor both environmental and cultural objectives.

The outcomes of this study include practical recommendations for architects and exhibition organizers and insights into balancing sustainability and functionality. This research aims to contribute to energy-efficient practices in Malaysian's cultural infrastructure, aligning with ecological and cultural objectives.

ACKNOWLEDGMENT

The main author would like to express his gratitude to Building Surveying Program of UiTM USM, especially the supervisor for funding this publication.

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OPTIMISING TIME, COST, AND QUALITY: THE ROLE OF SMART TECHNOLOGIES IN CONSTRUCTION PROJECT MANAGEMENT

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ABSTRACT

The integration of smart technologies in construction project management offers transformative potential to improve time, cost, and quality outcomes. Aligned with Malaysia's National Construction Policy 2030, this study examines the use of tools such as Building Information Modeling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), and automation to enhance project planning, communication, and risk mitigation. A quantitative survey of Malaysian construction professionals was conducted, with data analysed using reliability tests, correlation analysis, and factor analysis. The findings reveal that smart technologies improve scheduling, resource optimisation, stakeholder coordination, and defect detection, while also reducing costs through automation and real-time monitoring. Despite clear benefits, challenges such as high implementation costs and lack of training remain significant. The study confirms a strong correlation between smart technology adoption and project performance, with cost, training, and organisational readiness identified as key influencing factors. These insights offer practical guidance for industry practitioners and support the development of strategic frameworks to advance digital transformation in Malaysia's construction sector.

Keyword: Smart technologies, construction project management, time-cost-quality, digital innovation, project performance

I. INTRODUCTION

The global construction industry is experiencing strong growth, with China, the U.S., and India projected to account for 51% of global construction activities by 2037. This growth is driven by advancements in Construction 4.0 technologies, such as 3D printing, big data analytics, virtual reality, and IoT, which enhance efficiency and productivity. Leading nations, including the USA, UK, and China, are at the forefront of these innovations (Birruntha, 2024)

Malaysia's construction sector is benefiting from Chinese investments through the Belt and Road Initiative, with an expected RM180 billion allocations in 2024. Smart technology applications, like those used in the Hong Kong-Zhuhai-Macao Bridge project, could inspire similar advancements in Malaysia. The National Construction Policy 2030 aims to modernize the sector with digital technologies, boosting competitiveness, innovation, and sustainability (Todd & Slattery, 2018).

However, the industry faces significant challenges related to time, cost, and quality management. Delays often stem from poor planning, financial issues, and material shortages, while cost overruns result from inaccurate estimates and inadequate financial controls. Quality issues, including defects and rework, highlight the need for stronger supervision and quality management systems. To ensure sustainable growth, the construction sector must leverage smart technologies, improve project management practices, and adopt effective time, cost, and quality control measures

Smart technologies are increasingly integrated into various industries, transforming workplaces, education, healthcare, agriculture, and construction. Studies highlight their impact, such as enhancing rural development (Jakobsen et al., 2023), improving education through SMART systems (Nesterenko, 2023), advancing cardiovascular disease management (Khan et al., 2024), and optimizing agricultural processes (Pandey et al., 2022).

In the construction industry, research explores their role in sustainability (Umar et al., 2022), eco-friendly materials (Nilimaa, 2023), and safety improvements (Zairi et al., 2016). While smart technologies offer many benefits, challenges remain, as seen in studies on smart homes (Wilson et al., 2017) and UAVs in construction (McCabe et al., 2017).

However, a research gap exists in understanding how smart technologies specifically influence construction project management (CPM), especially within the Malaysian context. While international studies have explored the role of digital tools in enhancing project outcomes such as BIM in Europe and North America, or AI and automation in advanced economies like Singapore and South Korea, there is limited empirical evidence examining how these technologies are adopted and adapted in Malaysia. Most global research focuses on large-scale or government-led projects in digitally mature markets, whereas Malaysia's construction industry is still in the early stages of digital transformation, particularly among SMEs. This creates a need to explore how local factors such as organizational readiness, cost sensitivity, and workforce skills affect implementation.

Effective project management is crucial for minimizing delays, cost overruns, and inefficiencies. Exploring smart technologies in this context can enhance project efficiency, foster innovation, and improve client satisfaction, positioning companies to become more competitive in the digital era. Technologies like BIM and lean construction have shown success in reducing waste and improving coordination internationally, but their local performance and adoption challenges remain under-researched. This study addresses that gap by analyzing smart technology adoption in Malaysian CPM, identifying key success factors, and developing a practical framework to enhance efficiency, innovation, and stakeholder collaboration.

II. SMART TECHNOLOGIES FOR CONSTRUCTION APPLICATIONS

Smart technologies are autonomous systems integrating AI, ML, and IoT to enhance performance, productivity, and user experience through automation and data-driven decision-making.

Project management involves applying knowledge, skills, and tools to plan, execute, and control projects within time, cost, and scope constraints. It ensures efficient project completion while managing risks and stakeholder expectations.

Smart technologies in construction project management integrate digital tools, IoT, and data analytics to optimize time, cost, and quality. Key innovations include BIM for improved collaboration, drones and sensors for real-time site monitoring, and AI-driven analytics for predictive risk management. These technologies enhance efficiency, productivity, and decision-making, leading to better project outcomes and stakeholder alignment.

The "triple constraint" in construction project management time, cost, and quality are interdependent factors determining project success. Reducing project duration may increase costs or compromise quality, while cost-cutting can impact quality, leading to rework and delays. Effective management balances these constraints using tools like Earned Value Management (EVM) and Critical Path Method (CPM) to maintain efficiency and quality.

Modern construction project management extends beyond the traditional focus on tim`e, cost, and quality to include sustainability, safety, and productivity as key drivers of project success. Sustainability involves minimizing environmental impact through eco-friendly materials, energy-efficient designs, and waste reduction, which also enhance economic performance. Safety is a critical concern due to the high-risk nature of construction sites, and promoting a strong safety culture helps prevent accidents, reduce injuries, and avoid project delays. Productivity plays a vital role to ensure efficient resource utilization, with streamlining processes. By integrating these factors, construction projects can achieve greater efficiency, sustainability, and overall success.

Success in construction project management requires timely, cost-effective, and high-quality project delivery while ensuring safety, sustainability, and productivity. Continuous improvement involves integrating advanced technologies, enhancing quality and safety measures, and adopting automation to boost efficiency.

A. CHALLENGES IN IMPLEMENTING SMART TECHNOLOGIES IN CONSTRUCTION PROJECT MANAGEMENT

As illustrated in Figure 1, the challenges hindering the implementation of smart technologies in construction projects are multifaceted. These challenges include factors such as cost, lack of expertise, resistance to change, and insufficient infrastructure. Each of these elements plays a significant role in the slow adoption and integration of smart technologies into the construction sector. The figure provides a visual representation of how these challenges interrelate and impact the overall progress of technology adoption in construction projects.

Financial Challenges

High initial investment and capital costs remain the primary deterrents to adoption. Expenses related to software, hardware, training, and integration often exceed the budgets of small and medium-sized enterprises (SMEs), especially during economic downturns like the COVID-19 pandemic (Hatem et al., 2018; Yang et al., 2021). Additionally, many firms struggle to justify the return on investment (ROI), as financial benefits are difficult to quantify, especially in BIM-based projects that overlook indirect and maintenance costs (Hamadneh et al., 2021; Hewavitharana et al., 2021). For example, drone maintenance alone can account for up to 18% of the initial investment annually (Aibinu & Venkatesh, 2014), making long-term affordability a critical concern.

Organization Challenges

A significant barrier lies in the skill gap and limits digital literacy among workers, with insufficient training reducing the effectiveness of tools like BIM (Daniel et al., 2024; Hwang et al., 2022). In many countries, including Malaysia and Singapore, the reliance on foreign labor further complicates this issue. Additionally, organizational size and structure play key roles; larger firms may have the resources to adopt new tools, while SMEs struggle with cost and implementation (Silverio & Eng, 2019). Data security concerns also discourage firms from cloud-based platforms, especially where integration between systems like BIM and asset management is poor (Tanga et al., 2022; Soman & Whyte, 2020). Resistance to change, particularly from senior management or firms with rigid hierarchies, further delays adoption (Lee et al., 2021)..

Technological Challenges

Technological readiness remains uneven across regions. Poor network infrastructure hampers real-time monitoring through IoT and sensors, especially in remote or underdeveloped areas (Zhong et al., 2016). Environmental conditions and outdated regulatory frameworks also create barriers. Even in advanced economies like Singapore, strict compliance requirements may delay digital implementation despite their long-term benefits (Chen et al., 2022; M. Reza et al., 2015). Moreover, **interoperability issues** between different software platforms lead to inefficiencies and data loss, despite attempts to standardize through formats like IFC (Costin & Eastman, 2019).

Societal Challenges

Mistrust in digital systems, particularly concerning data privacy and surveillance, remains a challenge (Nnaji et al., 2023; Häikiö et al., 2020). Workers may be hesitant to adopt wearables or cloud-based platforms due to fear of monitoring or data misuse. Cultural and generational factors also play a role while younger professionals are generally more open to technology, older workers may resist due to unfamiliarity or discomfort, highlighting the need for targeted training and gradual change management (Liu et al., 2024; Ogunrinde et al., 2020).

Implementation Challenges

The construction industry's fragmented nature creates difficulties in integrating technologies like BIM, IoT, and AI into cohesive systems (Sacks et al., 2020). The lack of practical implementation frameworks contributes to the gap between academic research and on-site application (Chen et al., 2022). Smart technologies often prioritize efficiency over long-term sustainability, neglecting economic and social considerations (Olawumi & Chan, 2018). Additionally, poor collaboration and communication among stakeholders limit the benefits of integrated systems, reinforcing isolated adoption rather than holistic transformation (Woodhead et al., 2018; Nasrun et al., 2014).

B. STRATEGIES IN ADOPTING SMART TECHNOLOGIES IN CONSTRUCTION INDUSTRY

Government & Industry Support for Smart Technology Adoption

The successful adoption of smart technologies in construction project management heavily depends on support from governments and industry leaders. Financial incentives such as subsidies, tax breaks, and research grants can help reduce the high initial costs of adopting new technologies, making them more accessible to construction firms. Additionally, strategic initiatives aimed at enhancing workforce competency, such as specialized training programs tailored for construction professionals, can facilitate smoother integration of these technologies.

Raising awareness among decision-makers about technological advancements is also essential. Many company leaders are hesitant to embrace innovation, as senior professionals often resist change, while younger workers are more open to adopting new tools (Soto et al., 2019). Positioning technology adoption as a competitive advantage encourages firms to integrate tools like Building Information Modeling (BIM) and the Internet of Things (IoT) to enhance project quality and client satisfaction.

Organizational Strategies for Successful Implementation

Beyond financial and policy support, construction firms must establish structured internal strategies to ensure the successful implementation of smart technologies. Developing a clear and comprehensive strategic plan is essential for organizations to integrate technology effectively. Companies that proactively plan for these challenges are more likely to experience a smooth transition to digital construction management (Soto et al., 2019).

Shifting organizational culture to embrace innovation is another critical factor. Many firms in the construction industry are traditionally resistant to change, particularly when adopting unfamiliar digital tools.

Enhancing Workforce Competency and Collaboration

The workforce plays a crucial role in the successful integration of smart technologies. Without proper training and awareness, employees may struggle to utilize new tools effectively, reducing the overall benefits of digital transformation. Providing continuous education and professional development ensures that workers are well-equipped to operate and optimize smart technologies such as BIM, AI-driven project management software, and IoT- hesitate to invest in smart technologies due to uncertainty about their benefits or long-term return on investment. Furthermore, creating a more favorable market environment through regulatory support and policy incentives can encourage firms to take bolder steps toward digital transformation (Olawumi & Chan, 2018).

Effective stakeholder engagement is another key component of technology adoption in construction. The successful implementation of smart technologies requires seamless collaboration between various stakeholders, including contractors, architects, suppliers, and technology vendors. These tools improve project coordination, reduce errors, and enhance decision-making efficiency. Moreover, early stakeholder involvement in the planning and implementation phases helps mitigate risks associated with miscommunication, rework, and project delays (Woodhead et al., 2018).

Practical Approaches for Technology Integration & Cost Management

Despite the many advantages of smart technologies, their widespread adoption in construction is often hindered by cost concerns and integration challenges. To address these issues, firms must develop strategic cost management plans that optimize the financial feasibility of adopting smart technologies. One approach is to emphasize the long-term operational savings, and efficiency gains these technologies provide. Additionally, leveraging low-cost digitization tools can offer an affordable entry point for smaller firms that may not have the financial capacity to invest in large-scale digital transformation all at once. Incremental adoption strategies allow firms to implement smart technologies in stages, reducing financial strain while gradually realizing their benefits (Hamadneh et al., 2021). A well-structured data management plan is also critical to the success of smart technology integration. As digital tools become more prevalent in construction project management, cybersecurity threats pose significant risks to sensitive project information (Yang et al., 2021).

III. RESEARCH METHODOLOGY

This study adopts a quantitative research approach using a structured questionnaire to examine the impact of smart technologies on construction project management in Malaysia. A quantitative-only method was chosen due to its effectiveness in capturing generalizable patterns across a diverse group of industry practitioners. This approach allows for the application of statistical techniques to identify relationships among variables such as technology benefits, implementation challenges, and strategic adoption measures, which aligns with the study's objective of developing practical, data-driven insights for the industry.

The target respondents include contractors, developers, and consultants, three key stakeholder groups in the Malaysian construction industry. This selection ensures that the study reflects a wide range of professional viewpoints related to project delivery and smart technology use. A pilot test involving 35 respondents was first conducted to validate the questionnaire's clarity, structure, and reliability. Based on the feedback, minor adjustments were made before proceeding to full-scale data collection.

The final questionnaire consists of four sections. Section A gathers demographic data such as job role, years of experience, and firm size. Sections B to D use a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to assess smart technology application, adoption challenges, and implementation strategies, respectively.

To ensure the appropriateness of the sample size, this study follows the Central Limit Theorem and the "Rule of 5," which recommends a minimum of five respondents per variable for factor analysis. As the study includes 20 challenge-related variables, a minimum of 100 responses was deemed sufficient. Ultimately, 110 valid responses were collected from industry professionals, providing a robust dataset for further statistical analysis and enhancing the reliability and generalisability of the findings.

All participants were informed about the purpose and scope of the research before completing the questionnaire. Participation was entirely voluntary, and respondents were given the option to withdraw at any point. No personally identifiable information was collected, and all responses were kept confidential and analysed anonymously. These measures ensured compliance with basic ethical research standards involving human participants.

Table 1: Respondent's Demographic

Parameter	Category	Response	Frequency (%)
Role	Developer	7	20
	Consultant	19	54.3
	Contractor	9	25.7
Working Experience	<5 years	5	14.3
	5-10 years	15	42.9
	11-15 years	8	22.9
	15-20 years	5	14.3
	>20 years	2	5.7

3.2 Data Analysis

3.2.1 Reliability of the Scale used

Table 2 presents the alpha values for each section of the questionnaire. As shown in Table 1.1, all sections exceeded the 0.70 threshold required to ensure internal consistency (Yap et al., 2021). This indicates that the data demonstrated satisfactory reliability, confirming the study's credibility. Since no modifications were made to the pilot study questionnaire, all 35 responses were incorporated into the main study.

Table 2: Cronbach's coefficient alpha values for the pilot study.

Category Of Variable	No. of Items	Cronbach's Alpha
Challenges	20	0.889
Strategies	12	0.854

3.2.2 Ranking of Challenges and Strategies for Application of Smart Technology

The analysis of top five challenges in adopting smart technologies in construction (table 3) highlights initial investment & capital cost as the most significant barrier (m = 4.31, sd = 0.676). This suggests that the high upfront costs of procurement, installation, and training deter firms from adopting smart technologies, particularly smaller companies with limited financial capacity (zhou et al., 2022; li et al., 2021). The fact that developers (m = 4.7) rated this challenge highest implies that investment decisions largely depend on financial feasibility, making cost reduction strategies and government incentives crucial for accelerating adoption. Organization size and skill shortages & training gaps (m = 4.17) were also key concerns, indicating that both firm capacity and workforce readiness influence technology implementation. The variation in responses (sd = 0.857) suggests differing levels of preparedness across firms, with contractors (m = 4.33) expressing the greatest concern. This supports wang et al. (2020), who highlighted that a lack of skilled labor and resistance to digital transformation hinder smart technology integration. The disparity in ratings suggests that while larger firms may have training resources, smaller firms struggle with upskilling, reinforcing the need for industry-wide workforce development initiatives (chen et al., 2019). Organization data privacy & it security (m = 4.09, sd = 0.981) ranked slightly lower but remains a critical challenge, especially for contractors and consultants. Concerns over cybersecurity risks, data breaches, and unauthorized access discourage firms from fully adopting cloud-based solutions (Liu et al., 2022). This reluctance indicates the need for robust cybersecurity measures and clear data protection frameworks to build confidence in digital adoption (Liu et al., 2024; Qi et al., 2019; Ogunrinde et al., 2020).

Finally, uncertainty in estimating financial benefits (m = 4.03, sd = 0.923) was the least significant challenge but still notable. Developers (m = 4.14) and consultants (m = 4.21) expressed more concern than contractors (m = 3.56), suggesting that contractors may perceive greater direct benefits from technology adoption. This finding aligns with gao et al. (2021), who noted that many firms hesitate to invest in emerging technologies due to unclear cost-benefit projections. The variation in perceptions suggests that firms require better financial modeling and case studies to assess long-term returns on investment (Sacks et al., 2020).

Overall, financial barriers, workforce limitations, and security concerns remain the dominant challenges in implementing smart technologies. Addressing these issues requires targeted financial support, workforce training programs, and stronger cybersecurity frameworks to enhance adoption across the industry (Perera et al., 2022).

The analysis of the top five strategies for adopting smart technologies in construction (Table 4) reveals a strong emphasis on financial support, knowledge enhancement, and strategic planning. The highest-ranked strategy, providing training and education for employees (Mean: 4.60, Rank: 1), highlights the industry's recognition that

workforce capability is crucial for technology adoption. Without adequate training, employees may struggle to utilize new tools effectively, leading to resistance and inefficiencies. By equipping workers with the necessary skills, companies can enhance productivity and ensure a smoother transition into smart construction practices (Sacks et al., 2020).

The second most important strategy, government support and financial incentives (Mean: 4.51, Rank: 2), reflects the significant financial burden associated with adopting smart technologies. Many construction firms, particularly smaller ones, may lack the capital required for large-scale implementation. Government incentives, such as tax breaks, subsidies, and grants, help mitigate these financial constraints and encourage wider adoption (Perera et al., 2022). Additionally, strong governmental backing provides confidence in the long-term viability of smart technology investments.

Equally ranked in third place, creating a clear strategy to implement smart technologies (Mean: 4.51, Rank: 3), is essential for ensuring a structured and goal-oriented approach. Without a well-defined roadmap, companies risk investing in technologies that may not align with their operational needs. A strategic framework allows firms to allocate resources effectively, manage risks, and integrate new systems seamlessly. This highlights the importance of planning and foresight in successful technology adoption (Woodhead et al., 2018).

Boosting collaboration between industry and academia (Mean: 4.34, Rank: 4) emerges as another key strategy, emphasizing the role of research and knowledge exchange. Universities and research institutions serve as hubs for innovation, providing valuable insights into emerging technologies. Collaborating with academia enables construction firms to stay updated on the latest advancements and implement cutting-edge solutions. This partnership fosters knowledge transfer and bridges the gap between theoretical research and real-world application.

Finally, optimizing costs for smart technology adoption (Mean: 4.29, Rank: 5) underscores the financial challenges associated with implementation. While smart technologies offer long-term benefits, their initial investment costs can be high. To address this, companies must adopt cost-effective strategies, such as prioritizing high-return investments, phasing implementation, and leveraging scalable solutions (Woodhead et al., 2018). Effective budgeting ensures that technological advancements do not compromise the financial stability of construction firms.

Overall, these findings suggest that the successful adoption of smart technologies in construction depends on a combination of financial support, workforce readiness, strategic planning, collaboration, and cost optimization. While financial concerns remain a major hurdle, the industry's focus on training, structured implementation, and academic partnerships highlights a holistic approach to overcoming challenges.

3.2.3 Homogeneity of Perceptions across Different Respondent Groups

The Kruskal-Wallis H test was conducted to determine if there were significant differences in the perception of challenges among developers, consultants, and contractors. The results show that all p-values exceed 0.05, indicating no statistically significant differences among the groups. This suggests a shared recognition of challenges in adopting smart technologies in construction.

CONCLUSION

This study explored the impact of smart technologies on construction project management, shedding light on the key challenges and adoption strategies. The analysis identified significant barriers, including high initial investment costs, workforce skill shortages, and cybersecurity concerns, with financial constraints emerging as the most prominent obstacle. Despite variations in the level of concern across respondent groups, these challenges were universally recognized as critical for successful adoption. To overcome these barriers, the study emphasizes the importance of strategies such as workforce training, government financial support, strategic planning, academic collaboration, and cost optimization. These strategies are essential not only to mitigate the challenges but also to create a sustainable path toward the integration of smart technologies within the construction sector. The findings of this study contribute to both theory and practice. From a theoretical perspective, they expand our understanding of the barriers and enablers of smart technology adoption in the construction industry, offering a framework for future research in this area. Practically, the study provides actionable insights for construction firms, policymakers, and academic institutions, highlighting the importance of financial incentives, skill development, and structured implementation plans. These insights are crucial for fostering an environment that supports the widespread adoption of smart technologies, ultimately driving efficiency, innovation, and sustainability in the industry.

Beyond individual organizational improvements, the findings have wider policy implications. The results can support national efforts such as the implementation roadmap for the National Construction Policy 2030, providing evidence-based insights into current industry needs and readiness. Furthermore, the study highlights critical skill gaps that can inform curriculum development in higher education and training institutions, ensuring that future construction professionals are well-equipped to lead digital transformation. This enhances the study's real-world impact by aligning research outcomes with Malaysia's broader strategic and educational goals. By addressing these challenges and implementing the proposed strategies, stakeholders can pave the way for a more innovative, efficient, and competitive construction sector, with the potential for long-term growth and development. However, this study has several limitations. The research primarily focused on the perspectives of industry professionals, such as managers, engineers, and quantity surveyors, and did not fully capture the viewpoints of other key stakeholders, such as government officials or related agencies. This lack of diversity in perspectives may limit the comprehensiveness of the findings. Additionally, the study relied on a Likert scale survey, which can introduce response bias, as respondents may be inclined to select neutral or socially desirable answers. Future studies should aim to include a broader range of stakeholders, employ diverse research methods, and explore the long-term effects of smart technology adoption across different contexts. A more holistic and multi-faceted approach will be essential to accelerate the widespread adoption of smart technologies, promoting greater efficiency, innovation, and sustainability within the construction industry.

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Appendix:

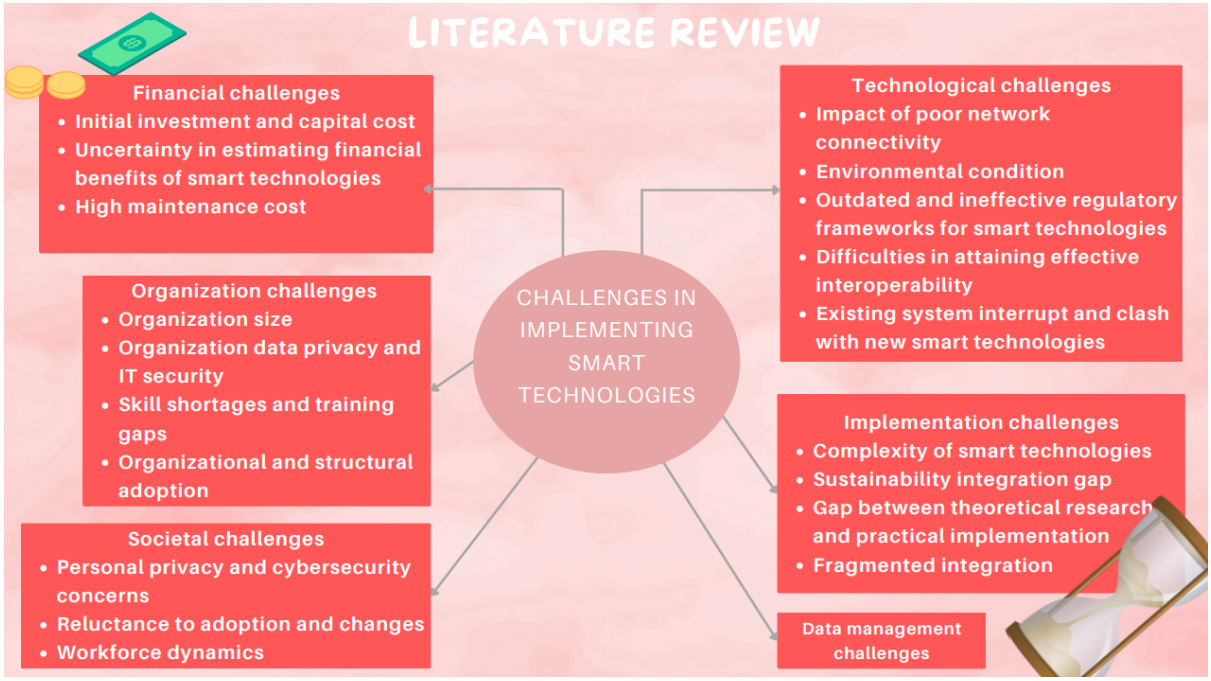


Figure 1: Challenges of Implementing Smart Technologies

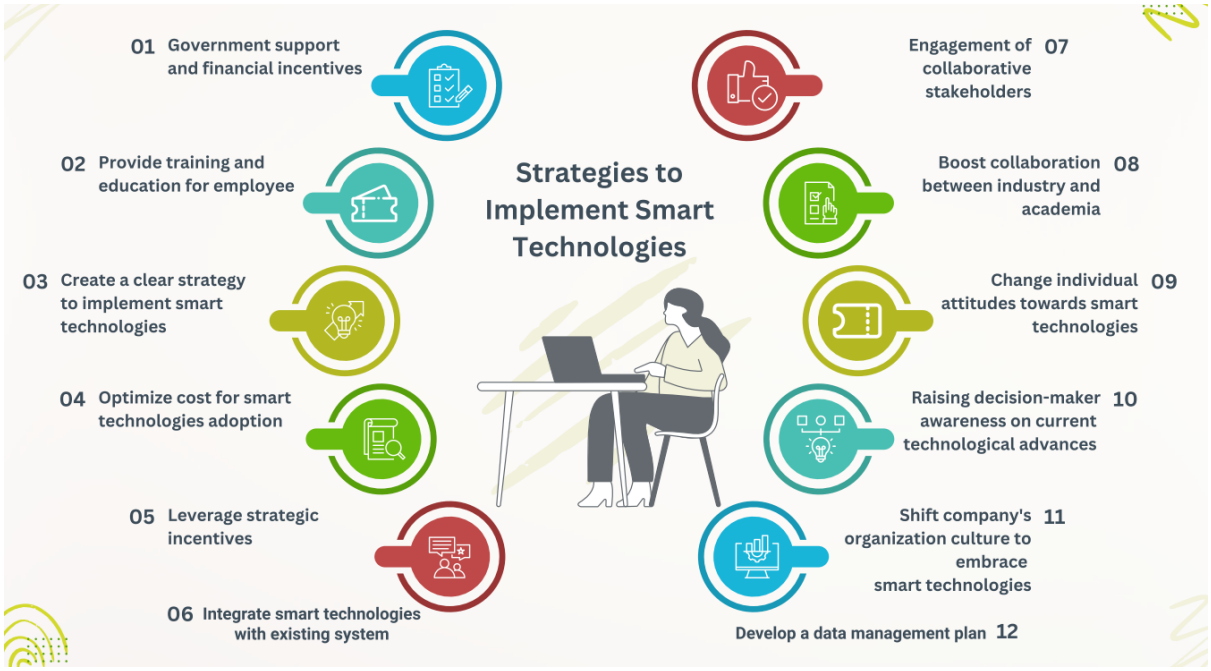


Figure 2: Strategies of Implementing Smart Technologies

Table 3: Table of Ranking of Challenges

Challenges	**Overall (N=35)**			**Developer (N=7)**			**Consultant (N=19)**			**Contractor (N=9)**			**Chi-Square**	**Asymptotic significance**
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
Initial Investment & Capital Cost	4.31	0.676	1	4.7	0.488	1	4.263	0.7335	12	4.111	0.6009	3	3.617	0.164
Organization Size	4.17	0.747	2	4.29	0.756	2	4.21	0.713	2	4	0.866	6	0.592	0.744
Skill Shortage & Training Gap	4.17	0.857	3	4	0.577	3	4.16	0.898	4	4.33	1	1	1.553	0.46
Organization and Structural Adoption	4.11	0.718	4	4.29	0.756	4	4.16	0.501	11	3.89	1.054	13	0.758	0.685
Organization Data Privacy & IT Security	4.09	0.981	5	4.14	0.9	8	4.41	0.9	5	4	1	6	0.15	0.928
High Maintenance Cost	4.09	0.702	6	4.14	0.690	5	4.0	0.667	2	4.22	0.833	2	0.734	0.693
Reluctance to adoption and changes	4.09	0.951	7	3.71	1.113	13	4.32	0.749	1	3.89	1.167	12	1.955	0.376
Uncertainty in Estimating Financial benefits of Smart Technologies	4.03	0.923	8	4.14	0.378	6	4.14	0.378	3	3.56	1.333	19	1.647	0.439
Outdated and Ineffective regulatory frameworks for smart technologies	4.00	0.939	9	4.00	0.577	9	4.16	0.834	4	3.67	1.323	17	0.91	0.634
Gap between theoretical research and practical implementation	3.97	1.014	10	3.57	0.976	14	4.16	1.015	5	3.89	1.054	11	2.2330	0.327
Complexity of Smart Technologies	3.97	0.891	11	3.86	1.069	11	4.05	0.78	8	3.89	1.054	9	0.138	0.934
Existing system interrupt with new smart technologies	3.94	0.968	12	3.570	0.976	15	4.21	0.855	3	3.67	1.167	15	3.201	0.202
Workforce dynamic	3.89	0.832	13	3.57	0.535	16	3.89	0.875	17	4.11	0.928	5	2.502	0.286
Sustainability	3.83	0.857	14	3.57	0.976	17	4.11	0.737	7	3.44	0.882	18	3.744	0.154
Difficulties in attaining effective interoperability	3.83	0.822	15	4.14	0.69	7	3.79	0.855	14	3.67	0.866	16	1.31	0.519
Fragmented integration	3.83	0.923	16	3.86	1.069	10	3.84	0.898	15	3.78	0.972	14	0.49	0.976
Data Management	3.83	0.822	17	3.86	0.9	12	3.79	0.713	16	3.89	1.054	8	0.183	0.913
Environmental Condition	3.66	0.968	18	3.29	1.38	18	3.58	0.902	18	4.11	0.601	4	2.765	0.251
Impact of Poor Network Conductivity	3.57	1.008	19	3.00	1.00	20	3.63	1.012	19	3.89	0.928	10	2.985	0.225
Personal Privacy and Cybersecurity Concern	3.31	0.9	20	3.14	0.9	19	3.42	1.017	20	3.22	0.667	20	0.452	0.798

Table 4: Table of Ranking of Strategies

Strategies	**Overall (N=35)**			**Developer (N=7)**			**Consultant (N=19)**			**Contractor (N=9)**			**Chi-Square**	**Asymptotic significance**
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
Provide training and education for employees	4.60	0.604	1	4.43	0.787	5	4.58	0.607	2	4.78	0.441	1	1.071	0.585
Government support and financial incentives	4.51	0.658	2	4.71	0.488	1	4.63	0.597	1	4.11	0.782	5	4.226	0.121
Create a clear strategy to implement smart technologies	4.51	0.612	3	4.57	0.535	2	4.42	0.692	3	4.67	0.5	2	0.756	0.685
Boost collaboration between industry and academia	4.34	0.684	4	4.43	0.535	6	4.37	0.597	4	4.22	0.972	3	0.40	0.98
Optimize cost for smart technologies adoption	4.29	0.789	5	4.57	0.535	3	4.32	0.749	5	4	1	6	1.544	0.462
Leverage strategic incentives	4.26	0.657	6	4.57	0.535	4	4.21	0.631	6	4.11	0.782	7	2.022	0.364
Engagement of collaborative stakeholders	4.26	0.701	7	4.14	0.90	7	4.21	0.787	7	4.11	0.601	4	1.909	0.385
Integrate smart technologies with existing system	4.23	0.464	8	4.14	0.69	8	4.21	0.713	8	4.22	0.667	8	0.055	0.973
Raising decision-maker awareness on current technological	4.17	0.857	9	4.00	0.577	11	4.21	0.765	9	4.11	1.269	9	0.283	0.868
Shift company's organization culture to embrace smart	4.17	0.785	10	4.14	0.90	9	4.16	0.765	10	3.78	1.093	12	3.85	0.146
Change individual attitudes towards smart technologies	4.11	0.796	11	4.14	0.69	10	4.16	0.765	11	4.0	1.0	11	0.069	0.966
Develop a data management plan	4.09	0.781	12	3.86	1.069	12	4.05	0.705	12	4.11	0.782	10	0.117	0.055

DIGITAL TWIN-ENABLED CARBON CCOUNTING: AN INTEGRATION MODEL FOR THE MALAYSIAN CONSTRUCTION SECTOR

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ABSTRACT

The construction industry accounts for 39% of energy-related carbon (CO_2) emissions, making it one of the largest contributors to global carbon emissions. As a result, accurate carbon accounting is essential for promoting sustainable development and mitigating climate change. While carbon accounting is widely recognized globally, Malaysia's construction sector faces persistent challenges in ensuring accuracy, leading to inconsistencies in data reliability and hindering effective emission reduction strategies. This study proposes the integration of Digital Twin (DT) technology into carbon accounting practices within the Malaysian construction industry to enhance accuracy. Existing research highlights that DT technology improves precision, enables real-time tracking, and enhances carbon footprint predictions across the project lifecycle—from design to construction and operation. To achieve this, the study will conduct a comparative analysis of global best practices, mapping them onto Malaysia's current carbon accounting workflow. Additionally, a technical gap assessment of DT implementation in the local industry will be carried out to identify key challenges and opportunities. The findings will lead to the development of an actionable model for DT adoption, detailing essential tools, processes, and strategies for accurate carbon accounting in Malaysia's construction sector. This research aims to provide practical guidance for policymakers and industry stakeholders, enhancing the accuracy, reliability, and effectiveness of carbon accounting. In the long run, these improvements will strengthen Malaysia's carbon management capabilities, contribute to more sustainable construction practices, and support the country's transition toward a more economically viable and environmentally responsible industry.

Keywords: Carbon accounting, Digital Twin, Construction industry, Malaysia's carbon management

I. RESEARCH BACKGROUND

Malaysia's rapid urbanization, driven by Industry Revolution (IR) 4.0, has led to increased carbon emissions, particularly in the construction and transportation sectors. The construction industry significantly contributes to carbon (CO_2) emissions, primarily during the building operation phase due to high energy consumption in heating, ventilation, and air conditioning (HVAC), lighting, and material production (Yousif et al., 2022). The lack of energy-efficient building designs and the energy-intensive production of materials like cement exacerbate these issues, with cement production alone accounting for approximately 7% of global CO_2 emissions (Zainordin & Zahra, 2020; Holappa, 2020).

To address these environmental challenges, carbon accounting has emerged as a critical tool for tracking and managing CO_2 emissions. Carbon accounting consists of two key aspects: environmental carbon accounting, which involves measuring and reporting emissions, and financial carbon accounting, which manages carbon-related financial implications (Eric et al., 2010). Effective carbon accounting enables organizations to reduce emissions, improve sustainability, and support regulatory compliance (Weinhofer & Hoffmann, 2008). While measuring carbon emissions does not directly cause reductions, it raises awareness and encourages corporate engagement in emissions management (Department for Environment, Food and Rural Affairs (Defra), 2010).

However, Malaysia's adoption of carbon accounting is still in its early stages due to the absence of regulatory frameworks and national guidelines (Bank Negara Malaysia, 2022; Borie & Decq, 2016). Unlike the European

Union Emissions Trading System (EU ETS), which has successfully reduced emissions through structured policies, Malaysia lacks a systematic emissions monitoring and reporting mechanism (Dechezleprêtre et al., 2023; European Commission, 2024). Although the government aims for net-zero emissions by 2050 through initiatives like the Long-Term Low Emissions Development Strategy (LT-LEDS) and Bursa Carbon Exchange (BCX), current efforts remain insufficient due to limited regulatory enforcement and data accessibility.

When discussing data in construction, a significant challenge is obtaining reliable carbon data due to the lack of standardized formats, dedicated databases, and real-time acquisition methods. Conventional data management practices render accurate carbon accounting nearly impossible. In contrast, several developed countries, including Australia (Kaewunruen et.al, 2022), United Kingdom (Xu, et.al, 2024), and even our neighbor Singapore (Alva, et.al, 2024), have embraced digitalization to enhance the management of construction and building data. They have demonstrated that integrating Digital Twin (DT) technology with carbon accounting offers a promising solution for real-time emissions tracking and management in construction projects. The integration of DY technology with carbon accounting offers a promising solution for real-time emissions tracking and management in construction projects (Wright & Davidson, 2024; Zhang et al., 2024). DT models simulate and analyze building operations, energy consumption, and material usage, allowing for optimized resource allocation and improved carbon efficiency. Initially developed for aerospace applications, DT technology is now widely applied in industries such as healthcare, mining, and construction, often integrated with the Internet of Things (IoT) and Building Information Modelling (BIM) to enhance sustainability efforts (Arsecularatne et al., 2024; Kim, 2025).

Against this background, this study aims to explore how DT technology can support and enhance carbon accounting practices in the construction industry, with a particular focus on Malaysia. It seeks to advance our understanding of digital innovations in sustainable construction practices and their potential to mitigate the environmental impacts of the built environment.

II. PROBLEM STATEMENT

Accurate carbon accounting in the construction industry remains a challenge worldwide, and Malaysia is no exception (CEO Action Network & Climate Governance Malaysia, 2022). In Malaysia, as this movement is still emerging, the country faces two primary issues. First, the lack of standardization in carbon accounting methods undermines the reliability of the data, hindering effective tracking at the national level. Second, reported carbon emissions often fail to reflect actual emissions due to reliance on static, periodic data collection or generic data sourced from other countries—methods that do not provide real-time insights into energy consumption and carbon output (Bank Negara Malaysia, 2022). Both issues ultimately affect the accuracy of the reported carbon data.

The whole world recognizes that digital transformation is currently a superpower. In carbon accounting, accuracy can be significantly improved when digital tools support data acquisition and processing. However, in Malaysia, DT adoption for carbon management has been slow, and research in this area is scarce (Waqar et al., 2023; Adillah Ismail et al., 2022, Changsaar et al., 2022).A study by Mohamad Zaidi et al. (2024), which examined a case in Bertam, Penang, highlights the potential of DT technology to reduce energy consumption and carbon emissions in residential areas within tropical cities. The study demonstrated how DT modelling can assess the energy and carbon-saving potential of residential buildings. However, it also identified key limitations, such as its reliance on literature review data and typical Malaysian construction practices, which may not fully capture actual energy patterns in local residential buildings. Additionally, the absence of a Life Cycle Cost Analysis (LCCA) restricts the evaluation of the cost-effectiveness of energy-saving measures over time. These limitations underscore the urgent need for more comprehensive and accurate carbon accounting approaches in Malaysia's construction sector.

Figure 1.0 reveals that Malaysia lags in adopting DT technologies and advanced carbon accounting methods. This delay puts the country at a disadvantage in meeting its sustainability goals. In contrast, other nations have made significant progress in integrating Industry 4.0 technologies for carbon management. Consequently, this study will draw lessons from these countries (European Union, United Kingdom, Singapore) to provide valuable insights for improving carbon accounting practices in Malaysia. The figure highlights Malaysia's position on net-zero commitments compared to other countries. While Malaysia has set a target to achieve net-zero emissions by 2050, the figure shows that it lacks a concrete policy framework to support this goal. Unlike nations that have banned internal combustion engine (ICE) vehicles, Malaysia has yet to implement such regulations. The figure also indicates that while Malaysia has proposed incentives for renewable energy, it has not established a comprehensive carbon pricing mechanism. Additionally, there are no mandatory climate-related financial disclosures under the Task Force on Climate-related Financial Disclosures (TCFD). Compared to countries like the UK and the EU, which have well-developed net-zero strategies and regulatory measures, the figure suggests that Malaysia's policies remain in the early stages, requiring stronger frameworks, digital integration, and policy advancements to support its low-carbon transition. These policy gaps, coupled with the slow adoption of DT-

enabled carbon accounting in key industries like the construction sector, highlight the need for digital integration and regulatory advancements.

	Country	National Net Zero Target	Net-zero policy framework	ICE vehicle ban	Coal power phase-out	Carbon pricing	Mandatory TCFD reporting
ASEAN	Malaysia	Net-zero by 2050	None	None	Plans to phase out	Plans to introduce, with incentives in RE	None
	Indonesia	By 2060	None	None	None	Developing	None
	Singapore	By 2nd Half Century	None	By 2040	N/A	Carbon tax on large emitters only	None
Asia	South Korea	By 2050	2050 carbon neutral strategy	Diesel ban by 2025	Plans to phase out	Emission Trading Scheme	None
Global	United Kingdom	By 2050	Net-zero legislation by 2050	By 2030	By 2025	Carbon price floor	Compulsory
	United States	No later than 2050	None	Few states by 2030	Few states with moratorium	Few states with carbon price	None
	European Union	By 2050	Climate-neutral by 2050	Few member states by 2035	Few member states	Emissions Trading Scheme	None

Commitment | Partial commitment / WIP | No plans

Source: Climate Action Tracker, Climate Watch, World Bank, news articles

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Figure 1.0 Comparison of Malaysia and Regional Peers' Initiatives in Relation to the carbon regulations (Bank Negara Malaysia, 2022)

III. RESEACH QUESTION

Building on the problem statement, the research questions of this study are as follows:

i. What are the best practices for carbon accounting methods?

ii. How can DT tools be mapped across the carbon accounting workflow?

iii. What are the current DT capabilities and limitations in integrating with carbon accounting practices in Malaysia?

iv. How can DT implementation be improved to address existing gaps, drawing insights from international best practices?

IV. AIM AND OBJECTIVES OF THE STUDY

Based on the problem statement outlined above, this study aims to propose a model demonstrating how DT technology can be utilized within the carbon accounting workflow to suit the Malaysian construction industry landscape, drawing on best practices from successful countries. The model will serve as a guide for early adopters in the construction sector, enabling reliable and accurate carbon reporting. To achieve this aim, the objectives of this study are outlined as follows:

i. To identify the best practices for carbon accounting methods.

ii. To evaluate DT tools within the carbon accounting workflow.

iii. To assess the current technical capabilities and limitations of carbon accounting practices in Malaysia.

iv. To propose an implementation model for DT-based carbon accounting in Malaysia, companied by strategic recommendations for enhancement.

V. PROPOSED RESEARCH METHODOLOGY

This study begins with a literature review aimed at meeting Objectives 1 and 2 by exploring the technical aspects of carbon accounting, such as calculation methods and data requirements, and, secondly, examining DT technologies and their integration with carbon accounting. The review also incorporates case studies from various countries on successful DT technology and carbon accounting projects, emphasizing the technical methodologies, tools, and technologies employed, and offering a comparative view of best practices across different contexts. Based on the literature review findings, a mapping of DT will be developed in alignment with the carbon accounting workflow, incorporating best practices identified in successful implementations.

The literature review will be conducted over five years, from 2019 to 2024, using a systematic search of

databases such as Scopus, Web of Science, and Google Scholar with keywords "carbon accounting," "Digital Twin," and "integration." Only English-language studies meeting predefined inclusion criteria were selected, and data were extracted using standardized forms. The quality of the selected studies will be appraised, and a thematic synthesis will be performed to compare best practices and technical methodologies across different contexts. To achieve Objective 3, a survey will be conducted targeting Malaysian quantity surveyors with experience in carbon accounting or DT technologies. This survey aims to gather insights regarding the adoption, challenges, and opportunities related to these technologies among Malaysian quantity surveyors. A questionnaire will be developed based on a comprehensive literature review and will include both closed-ended and open-ended questions. Prior to distribution, pilot testing will be carried out to ensure the clarity and relevance of the content and language. The target population consists of 5,825 registered members of the Board of Quantity Surveyors Malaysia (BQSM), with a required sample size of 361 respondents as determined by the Krejcie and Morgan table. Given that the number of quantity surveyors with experience in carbon accounting or DT may be limited, additional sampling techniques, such as snowball sampling or targeted outreach, will be employed. The survey will be conducted via an online survey platform. Following the survey, a gap analysis will be conducted to assess the limitations in Malaysia's carbon accounting practices by comparing them to global best practices. This will involve evaluating the technologies, tools, data integration, and methodologies currently used in Malaysia, focusing on areas such as the adoption of advanced tools like DT and BIM, the integration of carbon data, and adherence to international standards. The analysis will identify gaps and recommend improvements. To achieve Objective 4, a model for improving Malaysia's carbon accounting practices will be developed based on the findings from the literature review, survey, and gap analysis. This model will integrate best practices identified globally and propose recommendations for enhancing the adoption of DT technologies in carbon accounting. The proposed model will be validated through expert consultations, where industry professionals and academic experts will review its feasibility, applicability, and effectiveness in the Malaysian context. The final model will serve as a guideline for policymakers, industry practitioners, and researchers to enhance carbon accounting practices in Malaysia.

VI. LITERATURE REVIEW

A. Carbon Accounting

Carbon accounting is vital for managing CO_2 emissions in construction, enhancing transparency, efficiency, and compliance with climate goals (Blumberg & Sibilla, 2023; Trinks et al., 2020). In Malaysia, progress is underway toward the 2050 net-zero target, but challenges like data gaps, fragmented methodologies, and limited SME involvement persist (Bank Negara Malaysia, 2022; Labaran et al., 2022). Strengthening infrastructure, regulatory consistency, and sector-wide adoption is key to effective implementation. A comparative review of international carbon accounting practices reveals several best practices applicable to Malaysia's context. Countries such as the EU, UK, and Singapore adopt structured frameworks with clearly defined emission scopes (Scope 1, 2, and 3), localized emission factors, and real-time tracking systems like Singapore's SBCC, enabling more precise and accountable carbon reporting (RICS, 2012). These systems are typically supported by mandatory reporting regulations, centralized data repositories, and institutional incentives that drive continuous improvement and stakeholder compliance (Mota-Nieto et al., 2024; Ong et al., 2022). In contrast, Malaysia's current reliance on generalized IPCC factors and the absence of enforcement mechanisms has led to inconsistent, top-down estimations that limit operational-level carbon visibility (Bank Negara Malaysia, 2022; Mustaffa et al., 2022). Moreover, the absence of integrated digital platforms and inconsistent data granularity hinders project-level benchmarking and slows progress toward emissions transparency. Bridging this gap would require not only regulatory reforms but also a clear national roadmap for capacity building, digital integration, and sectoral alignment to scale carbon accounting effectively. By comparing these gaps with structured international systems, it becomes clear that adopting localized emission factors, formalizing reporting obligations, and encouraging integration with digital tools like BIM and DT would significantly enhance Malaysia's carbon reporting accuracy and decision-making capacity. These insights fulfill Objective 1 by identifying context-appropriate, evidence-based best practices that improve technical rigor and policy alignment in carbon accounting for the Malaysian construction sector More importantly, the findings establish a framework for policymakers to move beyond high-level emissions targets toward enforceable, quantifiable action at the project level. This is crucial for translating national climate goals into measurable outcomes within Malaysia's built environment.

B. Digital Twins

A DT is a virtual model of a physical object or process that collects real-time data to represent, simulate, and predict its behavior, enabling smarter and more efficient decision-making (Botín-Sanabria et al., 2022). DT technology consists of three core elements: the physical asset, its digital representation that mirrors structural and functional attributes, and the communication interfaces that ensure continuous synchronization between the two (Hananto et al., 2024). Key components include sensor-based data acquisition, high-fidelity virtual modeling,

advanced communication protocols for real-time feedback, and machine learning algorithms for diagnostics, forecasting, and optimization (Tripathi & Nishad, 2019). Together, these components form an adaptive system capable of simulating operational scenarios, optimizing performance, and supporting sustainability goals. However, widespread DT adoption remains constrained by high setup costs, limited access to skilled labor, cybersecurity risks, and fragmented standards that impede interoperability across platforms (Botín-Sanabria et al., 2022; Sharma et al., 2022). Real-time bidirectional data exchange also requires robust infrastructure like 5G and cloud computing, which are still evolving in many developing countries. In Malaysia, these issues are compounded by low digital maturity within the construction sector, limited BIM-DT integration, and the absence of national guidelines to standardize DT implementation. This gap restricts the scalability and replicability of DT-based carbon management solutions. As other countries invest in testbeds and innovation hubs for DT development, Malaysia risks falling behind in digital infrastructure readiness. Therefore, to fully leverage DT in Malaysia, the industry must prioritize investment in foundational technologies, develop DT implementation roadmaps, and build human capital through targeted training programs. This analysis enhances the theoretical grounding of Objective 2 by clarifying the structural and technological prerequisites for DT adoption and mapping their potential role in advancing sustainability across the construction lifecycle. By addressing both the systemic and operational barriers, this analysis bridges the gap between DT conceptual models and their scalable application in carbon-sensitive industries like construction.

C. Integration of Digital Twins in Carbon Accounting

The evaluation of DT integration across various case studies highlights their transformative potential in enhancing the precision and responsiveness of carbon accounting systems. In Malaysia's Bertam City, DT simulations enabled optimization of HVAC systems and solar PV integration, reducing projected emissions by 49.25%, thus demonstrating how virtual modeling can directly inform sustainable design decisions (Zaidi & Haw, 2023). Similarly, international examples like the PNIT port in Korea and the NOKSEL steel plant in Turkey illustrate the practical benefits of DT—enabling predictive maintenance, optimizing operations, and achieving significant reductions in energy consumption and carbon output (Eom et al., 2023; Ünal et al., 2023). These cases show that DT is not merely a digital monitoring tool but a dynamic platform for integrating IoT, AI, and BIM to simulate and visualize emissions in real time and across lifecycle phases (Zhang et al., 2024). In advanced economies, DT-enabled carbon monitoring is increasingly embedded within regulatory reporting frameworks and emissions trading systems. However, Malaysia's fragmented adoption—due to cost barriers, lack of policy incentives, and limited awareness—prevents construction firms from fully utilizing DT for emissions tracking and sustainability planning (Waqar et al., 2023; Adillah Ismail et al., 2022). Overcoming these barriers requires a phased adoption strategy supported by policy reforms, industry-government collaboration, and sector-specific pilot projects focused on high-emission building types. Establishing cross-sectoral standards and incentives for DT integration in sustainability reporting could further promote industry buy-in and accelerate deployment. Integrating DT into existing carbon accounting processes could significantly enhance data granularity, enable real-time emissions dashboards, and improve compliance with Malaysia's long-term climate targets. These findings reinforce Objective 2 by demonstrating how DT tools can operationalize carbon accounting workflows and generate timely, actionable insights that elevate sustainability performance in the construction industry. Furthermore, they provide a practical reference for industry stakeholders and regulators to co-develop digital carbon strategies, ensuring that DT integration is both technologically feasible and institutionally supported.

CONCLUSION

This study explores the integration of DT technology into Malaysia's construction sector to enhance carbon accounting accuracy, addressing challenges such as inconsistent data reliability and the lack of standardized reporting. By analyzing global best practices and identifying local industry gaps, the study aims to develop a DT adoption model to support policymakers and industry stakeholders in improving carbon tracking and sustainability efforts. However, a key limitation is the potential for a small number of survey respondents due to the novelty of DT technology in Malaysia, which may affect the generalizability of the findings. Additionally, constraints in accessing standardized carbon data and the evolving nature of digital innovations may limit the study's scope. Future research should focus on expanding industry participation and incorporating case studies to validate and refine DT-based carbon accounting models.

ACKNOWLEDGMENT

This study is conducted as part of the UM Global Transformation Research Grant (Grant No: GTRG008C-2024).

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DETERMINING THE FACTORS AND POTENTIAL OPPORTUNITIES IN UTILIZING BIG DATA FOR SARAWAK CONSTRUCTION INDUSTRY ORGANISATION

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ABSTRACT

The concept of big data emerged in the early 1990s, introducing new technological frameworks and architectural designs aimed at facilitating the rapid gathering, analysis, and interpretation of extensive and varied datasets to generate valuable insights. Within the construction industry, managing big data exhibits significant challenges, mainly due to the substantial sizes of 3D modeling files and the overwhelming volume of data accumulated daily. In Malaysia, the adoption of big data technology is still at an emerging stage, with full maturity anticipated to require several more years. Despite its potential, limited research has been conducted on the utilization of big data within the Sarawak construction industry. Therefore, the current study seeks to determine the factors influencing big data adoption and identify potential opportunities for its application within construction organizations in Sarawak. Through a comprehensive literature review, 19 influencing factors and 15 potential opportunities were identified. For further comprehensive research outcome, a qualitative research approach shall be employed, by utilizing purposive and snowball sampling techniques to select five participants from G7 construction firms in Sarawak registered with the Construction Industry Development Board (CIDB). The participants, each with over a decade of industry experience and foundational knowledge of big data, will provide insights through semi-structured interviews. The collected data will be analyzed using content analysis. This study aims to enhance awareness of big data's potential within G7 organizations in Sarawak, encouraging its adoption to improve efficiency and productivity in the construction industry.

Keywords: Big Data, Factors, Potential Opportunities, Construction Industry

I. INTRODUCTION

A. Background

In today's data-intensive construction industry, vast amounts of data are created but remain underutilized due to the sector's slow adoption of new technologies (Sepasgozar & Davis, 2018). The construction sector is increasingly vulnerable to data storage and collection overload because of the size and volume of data collected daily (Miller & Tolle, 2016). Big data in construction is still in its early stages and is expected to require several years to reach full maturity (Ullah et al., 2018). In order to promote the adoption of big data, it is critical to understand the factors and opportunities that drive its implementation (Ngo et al., 2021). Significant research has been conducted on big data adoption in construction, including studies of the challenges, benefits, and its diffusion in conjunction with other digital technologies (Lu et al., 2018; Koseleva & Ropaite, 2017).

Furthermore, big data offers numerous potential applications in the construction sector, including enhancing environmental and commercial sustainability. The implementation of big data analytics can potentially address current challenges faced by the construction sector and improve future outcomes. Leveraging historical and real-time project data could foster long-term infrastructure development and help prevent mistakes while improving quality (Munawar et al., 2022). According to McAfee and Brynjolfsson (2012), companies that adopt data-driven decision-making achieve 5% to 6% higher profitability than their competitors, a performance gain that can

contribute to overall Gross Domestic Product (GDP) growth. Thus, understanding the opportunities of big data is crucial, as it enables data-driven decision-making and helps construction stakeholders manage challenges more effectively (Zhang et al., 2015).

B. *Problem Statement*

Advancements in information technology have made it easier to rapidly gather, store, and process huge quantities of data (Fan & Bifet, 2013). This capability has prompted organizations in various industries, including government, healthcare, banking, manufacturing, education, retail, and infrastructure, to implement big data solutions, yielding financial and operational benefits (Narayan & Tan, 2019). Malaysia's construction sector today is more modern, efficient, and well-equipped than ever, enabling companies to undertake large, complex infrastructure projects using advanced methods (Khan et al., 2014). However, the adoption of big data technology in construction remains slow (Bilal et al., 2016). The generation of massive volumes of data in construction is forcing the industry to consider big data as a viable solution for complex technical problems (Alavi & Gandomi, 2017).

Notably, the Malaysian Ministry of Works (KKR) and CIDB have begun initiatives to encourage construction stakeholders to explore big data (CIDB Malaysia, 2016; SICA, 2017). Nevertheless, many Malaysian enterprises, especially small and medium-sized enterprises (SMEs), are reluctant to adopt big data technology because of the substantial time and resources required for implementation (Low et al., 2020; Saleh et al., 2019). Advancing knowledge on big data adoption in construction requires understanding its characteristics, benefits, challenges, and the specific factors and opportunities involved (Sepasgozar & Davis, 2018). While the construction sector has lagged in utilizing big data, most research focuses on its benefits and challenges in Peninsular Malaysia. However, little research has examined big data adoption in Sarawak, highlighting a gap in studies on the factors influencing and opportunities in Malaysia's construction industry. A better understanding of these factors and opportunities could accelerate the rate of big data adoption in Malaysian construction organizations. Therefore, the aim of the current study is to examine the utilization of big data in Sarawak's construction industry organizations. To achieve this aim, two research objectives are established, which are (1) to determine the factors affecting the adoption of big data in construction organizations in Sarawak, and (2) to identify the potential opportunities for utilizing big data in these organizations.

II. LITERATURE REVIEW

A. Factors Affecting the Utilization of Big Data for Construction Industry Organizations

As data generation in construction continues to increase, it becomes essential for organizations to adopt big data technologies to manage and analyze this information effectively. Construction companies generate large volumes of data through various sources, such as Building Information Modeling (BIM), computer-aided design (CAD), project management software, and site reports. To make effective use of this information, big data technologies provide the tools needed for efficient storage, processing, and analysis, ultimately enhancing decision-making and overall project performance.

Despite its impact, the adoption of big data in construction remains limited. A key factor is the low adoption of big data technologies in countries such as Singapore and South Africa, where integration of big data into construction projects is still undeveloped (Ngo et al., 2021; Aghimien et al., 2021). In addition, organizational characteristics significantly influence adoption. Firms with well-established IT departments are generally better equipped to implement big data solutions, improving productivity (Yu et al., 2020; Javed et al., 2020). Yu et al. (2020) also emphasized the importance of data sharing in China as a factor that determines the success of big data implementation. While effective data sharing fosters collaboration and coordination among stakeholders, it also raises concerns about data security and privacy. In response to such negative drivers, legislators in the US and the European Union have implemented specific regulations to protect organizational data (Iranmanesh et al., 2022). Apart from that, clients' support and satisfaction also play a vital role in achieving widespread adoption in the construction industry. Furthermore, Ngo et al. (2021) mentioned that the government and policymakers can launch programs that guide construction firms to implement big data solutions, ensuring a smoother transition and wider acceptance within the industry. Various factors, including competitive pressure, technological complexity, and market conditions, significantly influence the adoption of big data technologies. Organizations often adopt these technologies to stay competitive, but integration challenges can either promote or hinder adoption based on technological readiness. Additionally, market conditions like demand for efficiency and cost-effectiveness impact investment decisions, especially in uncertain times.

Therefore, identifying the key drivers and barriers impacting big data adoption in construction is crucial to understanding why organizations may or may not be willing to implement it. Gaining insight into these factors can help industry stakeholders, including decision-makers, policymakers, and technology providers, develop more effective strategies to promote the adoption of big data in construction practices. Based on previous studies and

literature, 19 relevant factors have been identified for this research, targeting construction organizations in Sarawak. These factors are outlined in Table 1.

Table 1: Factors Affecting the Utilization of Big Data for Construction Industry Organizations

No	Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Availability of big data technologies			/	/	/		/		/			/			/
2	Organization structure and culture	/			/	/	/	/		/		/				
3	Stakeholder management and collaboration					/				/						
4	Availability of big data facilities					/		/		/			/			/
5	Standards, handbooks, or guidance for utilizing big data					/										
6	Data sharing and governance				/	/	/	/		/	/	/		/		/
7	Client satisfaction					/	/				/		/			
8	Incentive policies		/	/		/	/					/		/	/	
9	Project performance				/	/					/		/			
10	Relative advantages		/		/							/		/		
11	Top management support	/	/			/	/		/			/		/		
12	Human resources				/	/	/	/		/	/	/				
13	Resistance to change		/		/	/	/									
14	Cost of adoption								/			/	/	/	/	
15	Complexity						/		/			/		/		
16	Competitive/Partner pressure		/	/	/		/		/			/		/	/	
17	Compatibility								/			/		/		
18	Market condition		/									/				
19	Big data quality	/					/			/			/	/		/

Source:[1] Yu et al. (2022); [2] Iranmanesh et al. (2022); [3] Ngo et al. (2021); [4] Aghimien et al. (2021); [5] Yu et al. (2020); [6] Javed et al. (2020); [7] Alharthi et al. (2017); [8] Verma & Bhattacharyya (2017); [9] Janssen et al. (2017); [10] Lee (2017); [11] Sun et al. (2016); [12] Bilal et al. (2016); [13] Paek et al. (2015); [14] Kang and Kim (2015); [15] Hashem et al. (2015)

B. Potential Opportunities in Utilizing Big Data for Construction Industry Organizations

Many organizations are leveraging big data to gain competitive advantages in their markets. By employing big data, big data in construction can help prevent mistakes and improve product quality (Munawar et al., 2022). Thus, it is important to know the opportunities of big data technologies because big data presents valuable opportunities across various sub-domains in the construction industry to enhance operational efficiency, reduce costs, and improve overall business performance. For example, big data enhances construction through resource and waste optimization by analyzing data for waste prevention (Munawar et al., 2022). It also supports data-driven design by optimizing building models to meet user needs (Yousif et al., 2021). Additionally, big data helps manage communication and data analysis from social networks (Ismail et al., 2018). Besides, big data improves various management areas in construction. Facility management benefits from real-time monitoring and predictive maintenance (Rane, 2023; Bilal et al, 2016). Energy management leverages data from building systems to optimize energy use and reduce costs (Ismail et al, 2018). Project management enhances decision-making, whereas data management allows efficient handling of large datasets, improving project tracking and resource monitoring through IoT and digital tools. Other than that, the digital revolution has significantly impacted the construction industry, with big data enabling technologies like BIM, cloud computing, IoT, smart buildings, and AR to improve collaboration, sustainability, data management, and efficiency. BIM integrates multi-dimensional data to foster collaboration, while cloud computing provides scalable infrastructure. The IoT generates large datasets for analysis, and smart buildings and AR enhance energy efficiency and project visualization. Together, these technologies drive better integration, innovation, and decision-making in construction. Moreover, big data also enhances sustainability in construction through BIM, supports data-driven decision-making for contractors, and improves safety on construction sites with IoT devices, ensuring better performance, productivity, and compliance (Rane, 2023).

Table 2 summarizes 15 potential opportunities for utilizing big data in Sarawak construction industry organizations, as identified from the review of literature based on previous research.

Table 2: Potential Opportunities in Utilizing Big Data for Construction Industry Organizations

No	Potential Opportunities	1	2	3	4	5	6	7	8	9	10
1	Resource and waste optimization		/		/				/	/	/
2	Data-Driven Design			/				/	/		/
3	Social networking services						/				/
4	Facility management	/	/		/						/
5	Energy management	/		/	/		/	/			/
6	Project management		/	/	/		/				/
7	Data Management			/			/		/		
8	Big Data with Building Information Modeling (BIM)	/					/			/	/
9	Big Data with Cloud Computing	/				/	/				/
10	Big Data with Internet of Things (IoT)	/				/	/				/
11	Big Data for Smart Buildings				/	/	/				/
12	Big Data with Augmented Reality (AR)	/					/				/
13	Sustainability	/	/		/						
14	Decision Support System	/					/		/		
15	Construction Site Safety	/		/	/		/				

Source: [1] Rane (2023); [2] Munawar et al. (2022); [3] Yousif et al. (2021); [4] Ram et al. (2019); [5] Garyaev & Garyaeva (2019); [6] Ismail et al. (2018); [7] Loyola (2018); [8] Maaz et al. (2018); [9] Mahmud et al. (2018); [10] Bilal et al. (2016)

III. RESEARCH METHODOLOGY

This study adopts an interpretivist research paradigm, preferring a qualitative method. An interpretivist approach is suitable for gaining an in-depth understanding of complex, context-dependent phenomena (Taherdoost, 2022; Mwita, 2022). In line with similar studies on big data in construction conducted by Yu et al. (2020), Maaz et al. (2018), and Ismail et al. (2018), a qualitative design will allow exploration of critical factors and opportunities that influence big data adoption. The research will focus on G7 construction companies in Sarawak. Given that big data technology in Sarawak's construction sector has not yet reached a mature stage, a qualitative approach is appropriate for uncovering rich insights into why construction organizations may be willing or unwilling to adopt big data, based on practitioners' real-world experiences.

A. Proposed Data Collection

Semi-structured interviews will be conducted using a pre-designed interview guide to ensure that a core set of standardized questions is covered with each participant. This consistency helps maintain the quality and comparability of the data collected (Young et al., 2018). Semi-structured interviews also offer flexibility, allowing the researcher to probe deeper into specific responses and explore emergent themes (Adhabi & Anozie, 2017). The interview guide is divided into four sections: Section A gathers background information on the interviewee's role and work experience; Section B addresses research Objective 1 (factors affecting big data adoption); Section C addresses research Objective 2 (potential opportunities for big data); and Section D invites any additional opinions or suggestions from the interviewee. All interviews will be recorded and transcribed with the consent of participants to facilitate accurate analysis.

B. Proposed Sampling Procedure

The study will employ purposive sampling followed by snowball sampling to select the potential participants. Purposive sampling involves deliberately selecting interviewees based on specific criteria relevant to the research (Vehovar et al., 2016). In this case, participants must have (1) at least 10 years of experience in the construction industry, (2) possess a basic knowledge of big data concepts, and (3) be a G7 construction firm registered with CIDB Malaysia. This is due to its typical handling of large-scale projects that generate substantial data. The researcher will start with a group of qualified individuals and continue interviews until no new information or patterns appear. This is called data saturation (Fusch & Ness, 2015). The focus is on collecting deep and meaningful insights rather than just having a large number of participants, since valuable findings often come from repeated discussions rather than big samples (Saunders et al., 2017).

After conducting the initial interviews, snowball sampling will be utilized, whereby the current participants will be requested to recommend other potential interviewees who meet the study criteria and could provide valuable insights (Parker et al., 2019). This referral process can help identify additional experienced professionals who might otherwise be difficult to reach. A similar approach was successfully implemented in a related study on technology adoption conducted by Verma & Bhattacharyya (2017). The combined purposive and snowball

sampling strategy ensures that the study engages experts and captures a breadth of perspectives until saturation is achieved.

C. Proposed Data Analysis

Interview data will be analyzed using content analysis, a systematic qualitative analysis technique for examining textual information (Mayring, 2014). The analysis will involve both within-case and cross-case examination of the interviews. Each interview transcript will be reviewed to understand participants' views. The text will then be broken into meaningful parts, assigned codes, and refined to ensure accuracy. Next, codes from all interviews will be compared to identify similarities and differences. Related codes will be grouped into broader themes that reflect key factors and opportunities discussed. The researcher will ensure that the coding accurately represents participants' perspectives. Finally, these themes will be analyzed to the study's objectives, exploring how organizational factors connect and why certain opportunities are valuable. This structured content analysis will provide insights into the key factors influencing big data adoption in Sarawak's construction firms and the opportunities they perceive in using big data (Brorsson, 2017).

D. Research Reliability and Validity

This research focuses on internal consistency reliability, which examines how well multiple observers or assessors agree on the same subject (Hajjar, 2018). It helps to ensure consistency and clarity in the study, making it more likely that other researchers can use the same methods (Rose & Johnson, 2020). This means that if different observers conduct the measurement again, the results should remain consistent. Additionally, recording interviews and providing full transcriptions can help to ensure procedural trustworthiness.

Internal validity will be ensured by checking whether the results accurately represent the studied population and are not affected by errors in methodology (Patino & Ferreira, 2018). In short, reliability and validity help maintain accuracy and ensure the research meets its objectives. Therefore, the research variables in the literature review are organized into a table to enhance internal validity. This ensures that the selected variables are relevant to the research topic, maintaining high validity and effectively achieving the study's objectives.

IV. POSSIBLE FINDINGS AND DISCUSSION

Based on the literature review shown in Tables 1 and Table 2, and the researchers' preliminary expectations, the study anticipates several key findings regarding the top 3 factors and opportunities for big data in Sarawak's construction industry.

Based on the preliminary predicted factors as shown in Table 1, the first factor, resistance to change, is expected to emerge as a major factor affecting big data utilization in Sarawak. Construction stakeholders may prefer traditional construction management methods because older employees have less knowledge of big data and are more comfortable with the current practices. Second, an organization's structure and culture are likely to significantly influence big data adoption. An organization that fosters an innovative culture and employs specialized staff is better positioned to successfully implement big data solutions. In such organizations, clear leadership support and a revolutionary strategy can facilitate a smooth integration of big data into business processes. In contrast, firms lacking technical expertise or with rigid hierarchies may struggle to embrace data-driven approaches. Third, the complexity associated with big data technologies is anticipated to be a critical barrier. Implementing big data in construction involves collecting vast amounts of various data, classifying and storing this data, and then analyzing it for actionable insights. If employees find the software and analytical methods too complex to learn or use effectively, adoption will suffer. Furthermore, big data is a relatively new domain in Sarawak's construction sector, so it may require a significant amount of effort and time to make progress.

On the other hand, based on the preliminary predicted potential opportunities as shown in Table 2, the first potential opportunity is in project management. Leveraging big data could help project teams complete tasks in shorter durations and learn from past mistakes, thereby improving consistency and outcomes in future projects. For instance, by analyzing historical project data alongside real-time information, organizations can better forecast project durations, mitigate risks, and ensure that resources are allocated efficiently. Another key opportunity lies in construction site safety. Big data can analyze past incidents and hazard reports to detect risk patterns. Predictive models can identify dangers like unsafe conditions, enabling timely alerts and real-time monitoring. This helps site managers respond quickly, preventing accidents and ensuring a safer work environment. Additionally, integrating big data with BIM is expected to be a frequently mentioned opportunity. Big data can enhance BIM by providing up-to-date information streams that keep the digital building model current with on-site progress and changes. For example, by analyzing data to identify clashes or inconsistencies in plans and optimizing costs through better forecasting and resource management.

As the study progresses to actual data collection and analysis, these predictions will be examined against the interview findings. The discussion of results will compare the anticipated factors and opportunities with those reported by industry practitioners, noting any revelations or differences. For instance, if unexpected factors such as data security concerns or regulatory issues emerge from the interviews, those will be discussed in context. Similarly, if participants identify additional opportunities, for example, in facilities maintenance or client relationship management beyond those in Table 2, those findings will be integrated into the discussion.

The study will also explore the interrelations among factors and how they collectively influence big data adoption. For example, an organization with strong top management support might overcome resistance to change more certainly, or incentive policies might help compensate for the identified cost of adoption. By interpreting these, the discussion will provide a holistic understanding of what leads or impedes big data uptake in Sarawak's construction firms, and how organizations can benefit from the most promising big data applications.

CONCLUSION

This study is expected to yield valuable insights for both industry stakeholders and academics on enhancing big data adoption in the construction sector. The findings will specifically benefit G7 construction organizations in Sarawak by examining the key factors that influence their willingness to embrace big data and by highlighting practical opportunities where big data can add value. Increasing awareness of big data's potential and addressing factors that facilitate or hinder its use can encourage Sarawak construction firms to adopt big data technologies, advancing Construction 4.0. This adoption is expected to enhance efficiency, productivity, and innovation, enabling firms to execute projects more effectively and competitively.

From an academic perspective, this research contributes to the growing knowledge of digital transformation in construction, focusing on Sarawak's understudied context. It bridges the gap between global big data concepts and local practices, examining adoption factors and opportunities to help construction organizations assess readiness and plan implementation strategies.

Additionally, the insights from this research provide a baseline for both academia and industry practitioners. By identifying key big data relevant to practice, academia can adjust curricula to equip future QS with essential skills for a data-driven construction environment. In conclusion, the study lays the foundation for better integration of big data in Sarawak's construction industry, driving the sector toward a more innovative and information-driven future.

ACKNOWLEDGMENT

The author would like to sincerely express thanks to the supervisor, Ts. Prescilla Anak Palis and advisor Ms. Stephanie Stella Anak Dawi, for their invaluable guidance and encouragement throughout the preparation of this conceptual paper for the 17th RISM-ISCU. Their dedication and patience are essential to the completion of this study.

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COMPARISON ON THE PERCEPTIONS OF DIFFERENT AGE GROUPS ON THE FACTORS AFFECTING ACCEPTANCE OF SMART HOME TECHNOLOGIES IN SARAWAK

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ABSTRACT

The adoption of smart home technologies (SHT) has been increasing globally, offering benefits such as energy efficiency, enhanced security, and improved quality of life. Despite the global advancement in SHT, Malaysia, particularly Sarawak, has lagged in its adoption rates, potentially possessing differences among age groups. Therefore, this study aims to prioritize the factors affecting acceptance of SHT in Sarawak and compare different age groups' perspectives on SHT, by categorizing respondents into young adults (16–30 years), middle-aged adults (31–44 years), and older adults (45 years and above). A quantitative method will be used to collect data through questionnaire surveys in Sarawak by using stratified sampling method. Descriptive statistics, including frequency, percentage, mean, and standard deviation, will be employed for analysis. The Kruskal-Wallis test will identify the statistically significant differences in among the three different age groups on the factors influencing their acceptance of SHT. The Mann-Whitney U Test will be used to compare two independent groups for determining whether their distributions are significantly different. Through an extensive literature review, 20 variables were identified. This study is expected to discover significant differences among the three different age groups, such as perceived cost may rank highest among middle-aged adults due to higher financial responsibilities and expectation for such technologies to provide clear benefits to justify the cost. The study emphasizes the need for affordable, user-friendly solutions and targeted education to address age-specific concerns and promote SHT adoption. These insights could assist policymakers, developers, and businesses for creating strategies to enhance SHT acceptance.

Keywords: Smart Home Technologies (SHT), Technology Acceptance, Age Group, User Perception

I. INTRODUCTION

The concept of "smart" buildings emerged in the U.S. in the 1980s (Hojjati & Khodakarami, 2016). Italy pioneered nationwide smart meter adoption, while Germany developed decentralized renewable energy networks (Marikyan et al., 2019b). Countries such as Canada, Singapore, and Japan have embraced smart home innovations (GhaffarianHoseini et al., 2013; Huynh, 2019; Kinsella, 2018). The sales of China's smart device surged by 90.5% between 2016 and 2021, with smart home adoption projected to grow by 28.3% between 2022 and 2023 (Van Wyk, 2022). Japan's market for smart homes was valued at ¥2.888 trillion in 2020 (Piller, 2016). These seems to indicate on a surge of smart home initiatives world-widely.

Moreover, governments worldwide incentivize smart home adoption. For instance, Japan offers energy-efficient grants (Piller, 2016), and the U.S., the U.K., and Canada provide financial incentives (Energy, 2023). Such initiatives could be arisen due to traditional buildings consume high energy and use fossil fuel, leading to an increase in carbon emissions (Ali et al., 2020). Building operations contribute significantly to environmental issues, with 65% of water consumption and nearly 80% of greenhouse gas (GHG) emissions (Hojjati & Khodakarami, 2016). In this sense, smart home technologies (SHT), such as automated lighting and appliances, could reduce electricity wastage, thereby lowering carbon footprints (Marikyan et al., 2019a).

Despite the benefits of SHT, adoption rates remain low in emerging Asian nations such as Malaysia, Singapore, China, South Korea, Thailand, and Indonesia (Yang & Lee, 2017). In 2020, Malaysia's household adoption rate was only 10.7%, significantly lower than the U.K. (34.8%), South Korea (31.2%), the U.S. (36.6%), and even neighbouring Singapore (23.5%) (Statista, 2023). This could be due to smart home functionalities often not aligned with Malaysian lifestyle preferences, as most systems originated from Western countries (Azlina et al., 2021). Studies had supported that despite the Malaysian government's investment of over RM500 million since 2015 in IoT, AI, and 5G infrastructure, smart home adoption remains slow (MIMOS Berhad, 2015). In Sarawak, the government only launched the smart home project in 2022, with projects like Centex Commercial equipping 652 residences in Samariang Avenue, indicating toward a slow adoption (Smart09sarawak, 2022).

Several studies on SHT had been conducted in Malaysia, including benefits (Rasyidah et al.,2020), challenges (Aziz & Nasir, 2021), and willingness to adopt (Lau et al., 2022). However, there seems to have little to no study focus on the varying age groups. One of the factors could be due to difficult level of technological acceptance among different generation. For instance, Venkatesh et al. (2012) found that younger individuals tend to exhibit higher levels of technological acceptance compared to older generations. Such varying technological acceptance could potentially affect different age groups' acceptance towards SHT. Therefore, this study aims to compare the perspectives of different age groups towards SHT in Sarawak.

II. LITERATURE REVIEW

A. Smart Homes: Definition and Concept

The smart home concept revolves around integrating various devices such as sensors, household appliances, and gadgets that can be remotely accessed and controlled to enhance convenience and security (Ozkan et al., 2014). This concept enables users to interact with systems to manage household functions like heating, air conditioning, and safety features (Yang & Lee, 2017). Unlike traditional appliances that require manual operation, SHT offer a more automated and intelligent home environment (Ozkan et al., 2014).

Smart home technology (SHT) initially focused on enhancing security and energy efficiency (Chen et al., 2010) but has since evolved with IoT integration, providing a wider range of services to meet consumer needs (Ferdhany & Aldianto, 2020). SHT incorporates pervasive computing, aiming to improve comfort, healthcare, security, and energy efficiency (Alam et al., 2012). The IoT connects smart devices such as computers, smartphones, smart TVs, and sensors, facilitating automation and remote control via mobile or computer systems (Wijaya & Jayadi, 2022). These technologies offer customized solutions, including security alerts, health monitoring, and reminders for elderly care (Nikou, 2019).

B. Theoretical Background

Previous studies identified various theoretical models including Technology Acceptance Model (TAM), Universal Theory of Acceptance and Use of Technology (UTAUT), Universal Theory of Acceptance and Use of Technology2 (UTAUT2), Innovation Diffusion Theory (IDT), and Maslow's Hierarchy of Needs. According to Davis (1985), the TAM and its extensions including UTAUT and UTAUT2 study user perceptions and actual usage and focus the factors such as performance and effort expectancy. Moreover, innovations spread throughout social systems is studied via the IDT (Rogers, 1995). These are complemented by Maslow's Hierarchy of needs, highlighting human motives ranging from self-realization to basic necessities (Maslow, 1943). These theories provide a theoretical basis on the user behaviours on the technology acceptance.

C. Factors Affecting the Acceptance of Smart Home Technologies

As users possessed different preferences on the SHT, Table 1 showed the factors affecting acceptance of SHT that identified from the literature review.

Table 1.0 Factors Affecting the Acceptance of Smart Home Technologies Identified from Literature Review

		References									
No	**Factors**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Perceived Usefulness	√	√	√	√	√	√	√	√	√	√
2	Perceived Ease of Use	√	√	√	√	√	√	√	√	√	√
3	Perceived Compatibility	√		√		√		√	√		
4	Perceived Convenience	√									
5	Perceived Connectedness	√		√		√		√			
6	Perceived Cost	√	√	√		√		√	√	√	√

7	Social Influence		√				√	√		√	√
8	Perceived Privacy Risk	√	√	√				√			√
9	Trust		√				√	√		√	
10	Perceived Behavioural Control	√									
11	Behavioural Intention		√		√	√	√	√	√	√	√
12	Habit		√								
13	Facilitating conditions		√					√			
14	Perceived control		√	√		√		√			
15	Perceived Enjoyment			√		√		√		√	
16	Actual Use				√	√		√			
17	Observability								√		
18	Personalisation									√	
19	Visual aesthetics										√
20	Policy subsidy and program						√				

Source: [1] Al Husamiyah and Al-Bashayreh (2022), [2] Tak et al. (2023), [3] Ferdhany and Aldianto (2020), [4] Hojjati and Khodakarami (2016), [5] Wijaya and Jayadi (2022), [6] Billanes and Enevoldsen (2022), [7] Neumann (2018), [8] Nikou (2019), [9] Mashal et al. (2020), [10] Yang et al. (2023)

Perceived Usefulness & Perceived Ease of Use

Perceived usefulness refers to the extent to which users believe that adopting SHT will enhance their quality of life. Studies have shown that perceived usefulness significantly influences behavioural intention (Tak et al., 2023). However, in Denmark, this factor had little impact due to a lack of awareness regarding energy savings (Billanes & Enevoldsen, 2022). Perceived ease of use also plays a significant role in SHT adoption, as users are more likely to accept technology that requires minimal effort (Mashal et al., 2020; Yang et al., 2023). While some studies highlight its significant impact (Nikou, 2019), others suggest that if a system is perceived as complex, users may lose interest (Baudier et al., 2020).

Perceived Compatibility, Convenience and Connectedness

Perceived compatibility is essential for adoption, as it minimizes the transition effort from older systems to new ones. Higher compatibility increases adoption rates, whereas incompatibility can cause stress, especially among individuals with limited technical knowledge (Neumann, 2018: Mashal et al., 2023). Similarly, perceived convenience, which relates to the ease of access in terms of time, location, and execution, significantly impacts perceived usefulness (Dong et al., 2017). Perceived connectedness, defined as users' ability to seamlessly connect and interact with smart devices, further enhances the ease of use and usefulness of SHT (Wijaya & Jayadi, 2022).

Perceived Cost

Perceived cost encompasses initial purchase, maintenance, and repair costs. Studies indicate that high costs discourage adoption (Nikou, 2019; Yang et al., 2023), though some research suggests that users remain open to SHT despite cost concerns (Tak et al., 2023).

Social Influence

Social influence refers as recommendations of friends, family, and other social circles that could influence the adoption of SHT (Tak et al., 2023). Bao et al. (2014) supported that the comment of friends and family is important in influencing adoption decisions for SHT.

Perceived Privacy Risk & Trust

Perceived privacy risk also affects adoption, as users may fear losing control over personal data. However, some studies found that users are often excited to try new technologies without fully considering privacy risks (Guhr et al., 2020). Trust is important to minimize social complexity and support confidence among stakeholders. In Finland, users fear losing control over automation (Tak et al., 2023). This distrust slows adoption, highlighting the need for better communication to build trust (Mashal et al., 2020).

Consumers' Behaviour

Consumers' behaviour in SHT adoption is influenced by perceived behavioural control, behavioural intention, and habit. Perceived behavioural control, shaped by past experiences and challenges, positively impacts behavioural intention (Al Husamiyah & Al-Bashayreh, 2022). Behavioural intention, driven by knowledge and

awareness, is a strong predictor of actual use (Neumann, 2018; Mashal et al., 2020). Additionally, habit plays a key role, as frequent use strengthens automatic behaviours, encouraging continued adoption (Tak et al., 2023).

Facilitating conditions & Perceived control

Facilitating conditions and perceived control are interconnected in influencing SHT adoption. While facilitating conditions provide external support, such as infrastructure, customer service, and technical assistance (Tak et al., 2023), perceived control reflects users' confidence in their ability to use SHT effectively (Neumann, 2018). A lack of facilitating conditions may reduce perceived control, leading to lower acceptance, especially among elderly users (Neumann, 2018). Conversely, well-developed facilitating conditions can enhance perceived control, making users feel more capable and willing to adopt SHT (Baudier et al., 2020).

Perceived Enjoyment & Actual Use

Perceived enjoyment and actual use are closely linked in SHT adoption. Perceived enjoyment, defined as the happiness users could experience while using SHT, serves as a key motivator for adoption (Baudier et al., 2020; Ferdhany & Aldianto, 2020). Enjoyable experiences, such as entertainment and convenience, can enhance actual use. Ultimately, actual use depends on prior experiences and factors like perceived usefulness and intention (Wijaya & Jayadi, 2022).

Observability & Visual aesthetics

Observability, a key factor in the IDT, impacts adoption by making the benefits of SHT noticeable. However, it does not directly affect perceived usefulness, ease of use, or intention to use, possibly due to users' lack of awareness of SHT benefits (Nikou, 2019). In contrast, visual aesthetics, including design elements like colours and shapes, significantly enhance perceived enjoyment and ease of use, influencing purchase decisions (Yang et al., 2023).

Policy subsidy and program

Government policies influence IoT-based SHT adoption through taxes, subsidies, and carbon trading (Billanes & Enevoldsen, 2022). While non-interest loans encourage adoption, end users often distrust government policies on smart homes (Yang et al., 2021). Stronger policy initiatives are needed to improve adoption (Kroener & Wright, 2014).

III. RESEARCH METHODOLOGY

A. Proposed Research Method

This study is proposed to adopt quantitative method. This method has been adopted by Tak et al. (2023). A quantitative method is appropriate as it determines influencing factors affecting acceptance of SHT in Sarawak, compares diverse age groups, and efficiently gathers large-scale data within a short timeframe.

B. Proposed Data Collection Procedures

Data will be gathered through an online questionnaire survey form with Google link be distributed via social media applications, while paper-based versions will be provided for older adults with limited smartphone access (Ebert et al., 2018). The questionnaire will be divided into three sections. The first section will capture the demographic details of respondent. The second section will focus in assessing respondent's familiarity with SHT. The third section seeks for respondents' agreeability on the factors that derived from literature review (refer to Table 1.0), by using a five-point Likert scale (Baudier et al., 2020; Neumann, 2018).

C. Proposed Sampling Technique

This study proposes to adopt stratified sampling technique to ensure representation across age groups. The population is divided into young, middle-aged and old adults, allowing more accurate and generalizable conclusions about their perspectives. This study targets Sarawak citizens aged 16 and above. According to the Department of Statistics Malaysia (DOSM), there are 1.933 million people in Sarawak who are 15 years old or older in 2021, indicating the unavailability of determining the required age group of 16 years old and above. However, the discrepancies shall not be crucial towards the sample size calculation due to the variance of 1 year old and large population. Slovin's formula will be used to ascertain the sample size of this study within the required accuracy as this formula allows to consider the confidence level (95%) and the margin error (5%). Therefore, the total sample size for this study will be 400 Sarawak residents aged 16 and above. The excepted number of respondents includes 32.5% young adults (130 residents), 30% middle-aged adults (120 residents), and 37.5% older adults (150 residents). These proportions are determined according to the population distribution reported by the Department of Statistics Malaysia (DOSM).

D. Proposed Data Analysis

Descriptive statistics will be used to analyze the information from the first and second sections of the questionnaire in order to summarize percentages and frequencies for respondent demographics, and respondent's knowledge and familiarity with SHT. The last section of the questionnaire will be analyzed using descriptive statistics, specifically focusing on calculating the mean and standard deviation. These calculations could identify variations in perceptions across different age groups regarding SHT. Moreover, Kruskal-Wallis test will be employed to compare the responses from the various groups for any discrepancies; while Mann-Whitney U-Test will be used to examine the significant differences of certain factors that identified from Krustal-Wallis test.

E. Research Reliability and Validity

This study employs a quantitative data collection method, which is similar as previous studies (e.g., Tak et al., 2023), to achieve interrater reliability. Additionally, the variables used in this study are drawn from previous literature, and the age group classifications are based on previous research. Moreover, Cronbach Alpha test will be used to analyse the internal consistency reliability.

To ensure content validity, six participants across the three age groups was recruited to review the questionnaire, for its clarity and accuracy. A duplication in ethnic classification was corrected, and factor definitions were revised. Additionally, Section C was reformatted into a multiple-choice grid to enhance responses' accuracy. External validity was ensured by including Sarawak residents aged 16 and above, while internal validity was strengthened by designing Section C based on literature review findings (Bonett & Wright, 2014).

IV. POSSIBLE FINDINGS AND DISCUSSION

This study is expected to identify three factors influencing SHT adoption in Sarawak and possessed statistically significant differences among the three age groups.

The high cost of SHT, including initial investment, maintenance, and operational expenses, remains a major concern for potential users. Many households, especially middle-income groups, may hesitate to adopt SHT due to budget constraints. If SHT remains costly, its adoption rate may stagnate, making "high perceived cost as a barrier to smart home adoption" a significant issue (Nikou, 2019). Moreover, the middle-aged adult (31-44 years old) may consider cost factor more important compared to the young adult and old adult. This could be due to middle-aged adults have more financial responsibilities in managing personal and family's expenses, and hence expect SHT to provide clear benefits to justify the cost. Hence, it is expected that there is statistically significant difference among these three age groups on the cost.

A lack of familiarity with SHT among different age groups may also affect its acceptance. Older adults, in particular, may struggle with new technology, and hence reduce their willingness to adopt it. Without proper knowledge and training, users may not fully utilize SHT's potential benefits, leading to lack of interest. Young and middle-aged adult, may easier to adopt SHT due to they are grown up with these technological devices and exposed to technologies in the working environment, respectively.

Privacy and security concerns are another key factor. Many users concern about data breaches, unauthorized access, and potential misuse of personal information. If smart home systems are perceived as unsafe, users may be unwilling to integrate them into their daily lives (Sovacool & Del Rio, 2020). The middle-aged group may be more concerned on the privacy and security as they are in the working age and often using the digital platform. The young adult may not be that concerned on privacy and security concerns of SHT, as this group may have high familiarity with technologies.

CONCLUSION

This study highlights critical factors such as perceived usefulness, ease of use, cost, security, and social influence, could affect SHT adoption among different age groups. Recognizing these factors enables stakeholders, such as consumers, developers, and policymakers, to enhance adoption through better affordability, education, and security measures. Effective implementation of SHT can improve convenience, energy efficiency, and overall quality of life. This study provides valuable insights to support informed decision-making and encourage wider SHT adoption in Sarawak.

ACKNOWLEDGMENT

The author would like to express her greatest thanks to supervisor, Sr Dr. Wong Shi Yee and advisor Ms. Stephanie Stella Anak Dawi. Their willingness for providing valuable advice and patient guidance has been a great help in this 17th RISM-ISCU's conceptual paper**.**

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CHALLENGES IN MAINTAINING BIM SOFTWARE FOR GREEN BUILDING PROJECTS IN MALAYSIA

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ABSTRACT

Building Information Modeling (BIM) has significantly enhanced the construction industry's ability to achieve sustainability by improving efficiency, resource management, and design accuracy. However, maintaining BIM software for green building projects in Malaysia remains a challenge due to factors such as skill shortages, high costs, software complexity, and interoperability issues. This paper aim to identify strategies for improving the maintenance of BIM software for green buildings in Malaysia. The objectives of this paper are (1) to determine the key barriers to maintaining BIM software for green building projects and (2) to analyse the impact of these barriers on the performance of green building projects. This paper uses a quantitative research methodology, structured surveys are conducted with industry professionals to assess these challenges. Next, this paper also uses descriptive analysis to analyse the acquired data and statistics to enhance data interpretation. The findings are forecasted to reveal that financial constraints and limited expertise are primary obstacles. The paper's contribution is expected to provide data-driven recommendations for optimizing BIM maintenance, fostering industry-wide adoption, and enhancing green building sustainability in Malaysia.

Key Words: BIM, Green building, sustainable, maintenance, software

I. INTRODUCTION

The construction sector faces the urgent task of mitigating its substantial ecological footprint while meeting increasing demand for sustainable structures. With approximately 37% of global energy-related CO2 emissions coming from the built environment (O'Hegarty & Kinnane, 2022), sustainable building practices have become crucial. These practices emphasize methods and materials that reduce waste, preserve energy and water, and limit pollution (Cheng, Q. et al., 2024).

Building Information Modeling (BIM) has significantly enhanced construction efficiency and sustainability. BIM is a collaborative method that uses digital 3D models enhanced with extensive data to improve the entire building lifecycle from design to operation (Yin, X, 2024). It enables optimization of daylighting, selection of environmentally-friendly materials, evaluation of renewable energy systems, and implementation of continuous control systems that reduce energy consumption and carbon emissions.

While some Malaysian construction projects, such as the Merdeka 118 skyscraper and MRT 2 project, have adopted BIM (Molarn, M.A. et al., 2024), its ability to deliver sustainable outcomes depends on effective maintenance throughout project lifecycles. The challenges of maintaining BIM software, including skill shortages, high implementation costs, and software complexity, can impede the achievement of sustainability goals (Onososen & Musonda, 2022). Addressing these maintenance concerns is essential to maximize BIM's potential for better environmental performance and more efficient project management in green construction.

II. ISSUES IN BIM SOFTWARE MAINTENANCE FOR GREEN BUILDING PROJECTS

Maintaining BIM software for green building projects faces several significant challenges. It is necessary to compose since it lays out the scope and precisely identifies the research challenges. When it comes to administering and maintaining BIM software, qualified experts are hard to come by. This gap is widened by the rapid growth of BIM technology, which calls for ongoing learning and adaptation to new tools and workflows. It

may be required to spend time to cultivate maintenance staff to use BIM software since BIM requires specific technical skills to operate with data and models (Carvalho, A.T. et al., 2023). Additionally, the variety of BIM software available such as Autodesk Revit and Bentley Open Building Designer, makes the maintenance staff more difficult, each platform has unique features and requires specialized training for each tool (Carvalho, A.T. et al., 2023). Besides, the lack of expertise and experience among industry participants about the use of BIM in green buildings is a major obstacle thus this lack of understanding may cause people to believe that adopting BIM is difficult (Cheng, Q. et al., 2024)

Furthermore, the implementation and upkeep of BIM software necessitate a significant financial investment in licensed software, such as Autodesk Revit, along with the required hardware and training as the learning curve is very steep, making it intimidating for teams and businesses that are unfamiliar with BIM (Yuvita, R.L. and Budiwirawan, A. ,2022). This problem is made worse by a lack of financing or financial incentives, which restricts the use of BIM software in green construction projects and lowers the possibility of productivity and efficiency gains. For instance, some businesses that engage in BIM but do not experience matching productivity increases may suffer from poor ROI because the software licensing is costly (Lin, L.Y. et al., 2023). If the program doesn't improve operational efficiency, the recurring expenses of software licensing and training may exceed the advantages.

Based on Gomes, A.M. et al. (2022) the technical difficulties brought on by the program's complexity and the massive amounts of data required in building projects are one of the main drawbacks of BIM software. As BIM software sometimes uses proprietary data structures and file formats, and information transmission between platforms can be challenging (Gomes, A.M. et al., 2022). Data loss, incompatibility, and the requirement for laborious manual solutions might result from this lack of interoperability (Gomes, A.M. et al., 2022). Furthermore, the sheer amount of data produced by BIM models can be debilitating, resulting in problems with version control, storage, and retrieval. Project delivery delays, mistakes, and inefficiencies may arise from this problem.

According to Zhan, Z. et al. (2022), a major hospital project that Spazevision worked on demonstrates the difficulty of maintaining BIM software for green construction projects. The team had the difficult challenge of converting the hospital's sustainability objectives into measurable BIM metrics during the build (Zhan, Z. et al. ,2022). With an emphasis on sustainability, the project entailed modeling a complicated network of components, such as the water, lighting, and HVAC systems. The work was made much more difficult by the necessity of guaranteeing precision and effectiveness in the BIM procedures in order to meet the project's

III. REVIEW OF MAINTAINING BIM SOFTWARE FOR GREEN BUILDING PROJECTS IN MALAYSIA

3.1 Definition of maintaining BIM software for green building

BIM is a digital representation of a building's functional and physical attributes, improving construction processes from design to operation compared to traditional 2D drawings. Green buildings, which aim to reduce environmental impact while enhancing energy efficiency, comfort, and sustainability, benefit from BIM's ability to minimize errors, optimize resource allocation, and improve energy analysis and lifecycle evaluations (Sofronievska et al., 2024). Proper BIM software maintenance ensures it remains efficient and aligned with evolving project requirements and industry standards by managing system updates and data integrity. Neglecting maintenance can reduce productivity, hinder decision-making, and impair efforts to enhance energy performance and lower carbon emissions, thereby compromising environmental outcomes (Sofronievska et al., 2024).

3.2 Current situation BIM software for green building in Malaysia

BIM adoption in Malaysia remains limited, particularly in small construction projects. Despite government efforts to promote green building, unclear regulations and organizational resistance hinder widespread acceptance (Rahim, N.S.A. et al., 2023). SMEs face additional challenges due to unfamiliarity with BIM standards and procedures, making it difficult to integrate BIM into workflows and achieve sustainability goals (Rahim et al., 2023). According to the survey, 71% of participants reported either low or very low levels of BIM usage, while only 23% indicated a moderate to high level of implementation., indicating that BIM implementation in Malaysia's small construction projects is extremely low, and SME contractor adoption is still behind (Waqar, A. et al., 2023). High implementation costs and limited awareness further impede adoption, underscoring the need for strategies that emphasize BIM's long-term benefits in achieving sustainability objectives (Zulkifli et al., 2024).

3.3 Barriers to maintaining BIM software for green building projects

Several barriers hinder the effective maintenance of BIM software for green building projects in Malaysia. A key barrier is the lack of awareness and adoption, as many stakeholders perceive BIM as costly and unnecessary due to limited understanding of its benefits in enhancing project efficiency and sustainability. Next, high initial costs, including software licenses, hardware upgrades, and training expenses, further deter adoption, particularly for smaller enterprises in developing nations (Husnain, n.d.). Additionally, the complexity of BIM software, especially when integrating sustainability data, creates interoperability issues and increases technical challenges (Mohammad & Azmi, n.d). Insufficient training and expertise exacerbate these challenges, it was found that "Lack of Skilled Personnel" is a significant obstacle to the implementation of BIM, states that 47% of respondents strongly agreed that it is a serious difficulty (Abdulfattah et al., 2017). Resistance to change within the construction industry, rooted in a preference for manual processes and traditional methods, further impedes adoption and effective maintenance. The absence of standardized information management practices also complicates BIM maintenance, leading to inconsistencies, data loss, and inefficiencies (Lai & Deng, 2018). Moreover, the vast data requirements of BIM can overwhelm teams unfamiliar with managing large datasets, resulting in errors and reduced efficiency (Ibrahim et al., 2023). Client apathy is another obstacle, as clients especially in smaller projects often do not prioritize BIM, discouraging contractors and stakeholders from maintaining the software (Olawumi et al., 2018). Limited market readiness for innovation further hinders BIM adoption and maintenance, with only 30% of Malaysian construction companies implementing BIM at any level, despite initiatives like the Construction Industry Transformation Plan (CITP) (Syed Jamaludin et al). Uncertainty about BIM data ownership and responsibilities can hinder implementation, as unclear ownership is a major barrier in green building construction phases, causing data management and stakeholder collaboration issues (Wong et al., 2025). BIM allows broad digital data sharing in green building projects, but the Malaysian construction sector's insufficient cybersecurity protections leave critical project data vulnerable to threats, hindering BIM implementation and maintenance (Wong et al., 2025). Finally, inadequate support from senior management undermines BIM maintenance efforts, as the lack of financial, technological, and human resource allocation reduces the effectiveness of BIM implementation and sustainability outcomes. These interconnected barriers collectively limit the potential of BIM to drive sustainable construction in Malaysia.

3.4 Impact of the barriers on the performance of green building projects

There are some barriers impact the maintenance of BIM software for green building projects in Malaysia, hindering sustainability performance and innovation. A lack of awareness among stakeholders reduces the adoption of BIM, leading to missed opportunities to conduct energy analyses, optimize design efficiency, and achieve long-term sustainability (Graham, 2023). Additionally, high software and training costs prevent smaller firms from fully adopting BIM, despite its potential to enhance project efficiency (Anwar et al., 2024). The complexity of BIM software further complicates maintenance, as firms struggle to manage large datasets, integrate sustainability metrics, and maintain project timelines (Husnain, n.d.). Skill gaps exacerbate these challenges, as insufficient training limits professionals' ability to preserve and transfer sustainability data, thereby impeding energy performance and carbon reduction goals (Mohamad et al., 2023). Resistance to technological change within the construction industry also affects BIM usage, with stakeholders often favoring traditional methods over innovative green construction techniques (Maali et al., 2020). Moreover, inadequate information management standards result in data inconsistencies that reduce BIM’s effectiveness in sustainability assessments (Lai & Deng, 2018). Complex data management further hinders performance by causing inaccuracies in sustainability metrics, increasing project risks, and delaying construction timelines (Hossain & Ng, 2020). Client apathy also limits innovation and collaboration, as a lack of demand for BIM discourages firms from adopting integrated project delivery methods that improve efficiency and reduce long-term costs (Moshood et al., 2024.). The market’s limited readiness for innovation restricts the development and broader application of BIM technologies, affecting Malaysia’s ability to meet national sustainability goals and compete globally in green construction (Rossoni et al., 2024). Lastly, insufficient administrative support hampers project collaboration, resource allocation, and the adoption of creative green design practices, thereby weakening the overall impact of BIM on sustainability (Hodorog et al., 2021). These barriers collectively impede the effective maintenance of BIM software, reducing its potential to enhance green building performance in Malaysia.

3.5 Strategies for improving

To enhance the maintenance of BIM software and improve green building performance in Malaysia, several strategic approaches can be implemented. Firstly, increasing awareness through targeted campaigns, such as seminars, workshops, and online marketing, can showcase successful BIM projects like MRT 2 and the National Cancer Institute, demonstrating BIM's role in optimizing lifecycle management, minimizing waste, and improving energy analysis (Molarn et al., 2024). Besides, offering financial incentives, including subsidies and tax breaks, can alleviate the high initial costs of BIM adoption, encouraging wider uptake, as evidenced by government-sponsored projects like Hospital Kemaman (Liu et al., 2015). Simplifying BIM interfaces can make the software more user-friendly, enhance communication, and optimize energy monitoring, helping site managers identify and address inefficiencies (Hmidah et al., 2022). Next, specialized training programs that combine technical skills with hands-on applications can bridge knowledge gaps and equip maintenance personnel to manage BIM effectively (Bozoglu, 2016). Fostering collaborative construction practices, such as Integrated Project Delivery (IPD) models, can strengthen real-time data sharing, reduce errors, and enhance sustainability outcomes (Ohueri et al., 2022). Establishing standardized BIM guidelines, modeled after frameworks like BS EN ISO 19650, can improve data consistency, reduce delays, and enhance lifecycle performance (Sherif, n.d.). Adopting modular BIM approaches can simplify complex data management by segmenting project models, improving coordination, and optimizing sustainability performance (Lluka, 2024). Strengthening industry leadership by promoting BIM's long-term benefits, such as reduced operating costs and improved energy efficiency, can overcome client apathy and encourage BIM prioritization (Olugboyega, 2022). Cloud-based BIM solutions further streamline collaboration by enabling real-time updates, minimizing errors, and reducing maintenance costs (Wang et al., n.d.). Finally, aligning BIM with Malaysia's national sustainability goals, like those outlined in the Green Building Index (GBI) and Construction Industry Transformation Programme (CITP), can enhance management support by showcasing how BIM contributes to decarbonization and long-term cost savings (Rahim et al., 2023). These interconnected strategies aim to improve BIM maintenance practices, ultimately promoting sustainable construction and innovation in Malaysia.

IV.RESEARCH METHODOLOGY

This study will adopt a quantitative research methodology to explore the challenges of maintaining BIM software in green construction projects in Malaysia. The research will specifically target stakeholders such as architects, engineers, designers, and quantity surveyors, as they will be directly involved in BIM related sustainable building efforts. By clearly specifying these stakeholders, the study will ensure that the data collected will represent the broader context of the construction industry and will provide insights that are reflective of real-world practice (Schneider et al., 2023). A structured questionnaire will be distributed to 159 professionals to gather quantifiable data on issues such as skill gaps, cost barriers, and awareness limitations. This approach will allow for broad, statistically valid generalizations that will support the research objectives.

The questionnaire will use a five-point Likert scale to measure respondents' attitudes, views, and perceptions, ensuring uniformity and simplifying statistical analysis (Doğan et al., 2023). To ensure that the questionnaire items are reliable and internally consistent, the study will use Cronbach's Alpha, a method widely recognized for evaluating the strength of the relationship between items in a scale, with acceptable values ranging from 0.70 to 0.95 (Tavakol and Dennick, 2011). SPSS software will be used for data analysis due to its powerful capability to perform both descriptive and inferential statistical tests efficiently (Sharma and Jha, 2023). Additionally, mean ranking will be applied to prioritize the identified challenges by calculating the average score for each factor, simplifying comparison and highlighting the most significant issues (Sial and Abid, 2023).

CONCLUSION

In conclusion, sustaining BIM software for green building projects in Malaysia is essential to sustainable construction, but skill shortages, financial restrictions, software complexity, and inconsistent data management practises hinder it. These obstacles hinder BIM's energy efficiency, waste reduction, and project coordination. Industry stakeholders should raise awareness through targeted campaigns, provide financial incentives to offset the high cost of BIM adoption, simplify BIM interfaces to improve accessibility, and develop specialized training programs to equip professionals with the necessary technical skills. Integrated Project Delivery (IPD) models can improve data exchange and project workflows by encouraging collaboration. Future researchers should examine the long-term effects of these tactics on BIM acceptance and sustainability, analyze technical breakthroughs that

could simplify BIM maintenance, and evaluate government-led incentives for BIM use. Future studies in these areas may help Malaysia's building industry promote sustainable construction and digital innovation.

ACKNOWLEDGMENT

The main author wishes to express her heartfelt gratitude to the Building Surveying Department of the UiTM Perak branch, especially the supervisor, for the invaluable guidance and steadfast support. She also deeply appreciates her supervisor's continuous encouragement and insightful advice throughout the preparation of this paper.

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IOT IMPLEMENTATION BY SMALL AND MEDIUM-SIZED CONTRACTORS IN PENANG : PRACTICES, CHALLENGES AND THE WAY FORWARD

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ABSTRACT

The advent of Construction 4.0 has driven the adoption of digital technologies to enhance and efficiency and productivity in Malaysia's construction sector. The Internet of Things (IoT) is a crucial a crucial component of Construction 4.0, offering significant benefits in project monitoring, resources management, construction health and safety and decision making throughout the construction process. Although previous research indicates that IoT adoption is gaining traction among small and medium-sized contractors, little is known about its implementation within these companies' construction operation. This study synthesizes findings from 20 peer-reviewed articles published between 2019 and 2024, retrieved from Scopus and Google Scholar, to address the limited adoption of IoT implementation within construction sector. Therefore, this study addresses this gap by developing a conceptual framework based on analysis of relevant research. The framework outlines three key components of IoT adoption, i.e, implementation aspects, challenges and strategies. It serves as a structured reference for further empirical investigation and provides guidance for contractors on effectively leveraging IoT. By offering insight into the IoT practices, berries and ways for overcoming them, this research to support small and medium-sized contractors in utilizing IoT technologies to improve company efficiency, competitiveness and project outcomes. The findings will also benefit the contractors and industry stakeholders by fostering a more technology driven construction environment.

Keywords: IoT, small and medium-sized contractor, construction 4.0, Malaysia

I. INTRODUCTION

The construction sector is essential to Malaysia's economy. To remain competitive in the global market, the adoption of modern technologies is crucial and Construction 4.0 was introduced as a transformative approach to managing, organizing and optimizing built environment with greater efficiency and effectiveness (Jaafar et al., 2024). Construction 4.0 is revolutionizing the sector by increasing productivity and structure. Even though programs like the CIDB Construction 4.0 Strategic Plan (2021-2025) have helped large firms implement technology, small and medium-sized organizations still face challenges because of high costs, a lack of experience, and resistance to change (Jaafar et al., 2024). Among the various construction 4.0 technologies, the Internet of Things (IoT) is one of a key enabler in digitalisation in construction, offering benefits such as enhanced safety, efficient resource management, and real-time project monitoring (Maqbool et. al, 2023). IoT also contributes to more sustainable construction practices, improve operational efficiency and enhance data-driven decision making (Lampropoulos et al., 2019). Although the advantages of IoT are well-documented, the underlying causes of its low adoption among small and medium-sized contractors remain insufficiently understood. However, there is insufficient clarity regarding the effective operationalization of IoT within these firms in Malaysia (see Jaafar et. al; Musarat et. al, 2024). This study aims to address these gaps by proposing a framework that serves as guide for contractors and industry in enhancing the implementation of IoT. The finding will provide valuable insight to support Malaysia's digital transformation agenda and strengthen the construction sector.

II.LITERATURE REVIEW

a. Small medium-sized Malaysian Construction Industry

The construction sector in Malaysia is essential to the country's economy (Tayib et al., 2022). Malaysian contractors are categorized as small, medium, or large based on their bidding capacity. While larger contractors compete on the international stage, small and medium-sized businesses support local economic growth (Arif et al., 2021). To ensure compliance with industry standards, all contractors must be registered with Construction Industry Development Board (CIDB) Malaysia before operating legally (Chidiebere et al., 2021).

Malaysian small and medium-sized businesses (SMEs), as defined by SME Corp under the National SME Development Council (NSDC), are categorized according to yearly sales turnover and full-time employees, with industry-specific differences. According to Singaram (2023), small and medium-sized contractors play a crucial role in the building industry by fostering innovation, social stability, and economic progress. These companies have a high degree of adaptability, which they use to quickly meet market demands and adopt new technology. In Malaysia, 36.2% of construction projects are completed by small and medium-sized contractors, who also contribute RM 20.6 billion and 5.5% of the total value of the construction industry (Zulkifli et al., 2023). Their capacity to promote competition, encourage creativity, and maintain local economies underscore their crucial role in shaping the future Malaysia' construction industry.

b. Adoption of Construction 4.0 among Malaysian Contractors

Construction 4.0 marks a transformative shift in the construction industry. It integrates automation, digital technology, and cyber-physical systems to improve productivity, sustainability, and efficiency (Zulkifli et al., 2023). Inspired by Industry 4.0, this evolution leverages big data analytics, artificial intelligence (AI), the Internet of Things (IoT), and Building Information Modelling (BIM) to modernize construction processes. In Malaysia, the adoption of Construction 4.0 aligns with key government Construction 4.0 Strategic Plan (2021–2025) and the government Construction Policy 2030 (NCP 2030), which seek to address skill shortages, increase sustainability, and lower prices. Malaysia's construction sector is leading the way in creating a built environment that is smarter, more robust, and prepared for the future by adopting Construction 4.0. According to Tayib (2022), digital transformation is now a must for small and medium-sized contractors in order to improve service delivery and competitiveness.

Internet of Things

The Internet of Things (IoT) is transforming Malaysia's construction industry by enabling real-time connectivity, automation, and data-driven decision-making throughout project phases (Dosumu et al., 2023). By building a network of interconnected sensors, devices and software, IoT improves resource management, operational efficiency, and safety by continuously monitoring, gathering, and analysing data with minimal human intervention (Tanko et al., 2023). As outlined in CIDB Strategic Plan 2021-2025, IoT integration in construction seeks to simplify operations from design to maintenance, boost collaboration, and improve project monitoring.

Below are the use of IoT in construction as analysed from previous research :

i. Workforce safety and health monitoring

Smartwatches and fitness trackers are examples of wearable technology that monitors employee presence and productivity, while Radio Frequency Identification (RFID) tags and sensors optimize material tracking and equipment usage (Singaram et al., 2023). Both employees' and workers' health and safety can be observed while they are at work to enhance productiveness.

ii. Real time site management and work monitoring

IoT reduces downtime and increases asset lifespan by enabling early detection of possible problems or maintenance requirements. IoT improves inventory management, reduces theft risk, and increases asset utilization through automatic asset tracking, which improves lifecycle management and saves maintenance costs (Rao et al., 2022).

iii. Equipment and Asset Management

Real-time tracking, monitoring, and predictive maintenance made possible by IoT transform equipment and asset management by identifying possible problems early on, cutting downtime, and increasing asset lifespan. By automatically tracking assets, it also improves inventory management by reducing the possibility of theft or misplacement (Rampini et al., 2022). Companies are able to minimize maintenance expenses and maximize

asset use thanks to this improved visibility.

iv. Energy efficiency and Asset Management

By detecting inefficiencies like overuse or needless heating and cooling and tracking energy consumption in real time across several devices, including HVAC and lighting systems, IoT improves energy efficiency. IoT can minimize its influence on the environment while optimizing energy use, forecasting needs, and generating cost savings by utilizing data analytics (Maqbool et al., 2023). It also encourages the use of renewable energy sources, which enhances operational effectiveness and sustainability.

v. Automated and compliance control

IoT monitors vital characteristics like temperature, humidity, and pressure in real time, automating and enforcing compliance in industries with stringent standards (Amor et al., 2021). When deviations happen, it automatically sends out alerts or takes corrective action to ensure compliance with industry and legal standards. Furthermore, audit trails are produced by IoT-generated data, which makes compliance verification easier and lowers the possibility of non-compliance or human error (Cheng et al., 2022).

Despite increasing awareness of Construction 4.0 technologies, adoption rates remain moderate, with IoT emerging as one of the most recognized and widely used innovations (Jaafar et al., 2024). IoT's ability to supervise mechanical, electrical, and electronic systems across residential, commercial, and industrial buildings further underscores its transformative impact on the built environment (Lawal et al., 2022).

Type of IoT Technology

Based on the importance of IoT in construction, numerous IoT technologies have been developed in the market to enhance safety, operational efficiency and project management. Data-driven, highly optimized processes are replacing traditional workflows thanks to important applications including wearable technology, drones, cloud computing, and real-time monitoring (Arif et al., 2021). Through automated systems, real-time monitoring, and smart sensors, IoT is transforming the construction industry by improving project management, efficiency, and safety. Some of the key IoT technology used in the construction industry include:

i. Wearable technology

Small and medium-sized contractors can increase worker safety, productivity, and cost effectiveness on construction sites by implementing wearable IoT technologies. In addition to automating timekeeping and streamlining workflow, smart gadgets assess employee health, identify falls, and send out real-time alerts. Wearables provide SMEs with an inexpensive means of improving site management and maintaining their competitiveness by cutting insurance premiums, preventing accidents, and guaranteeing compliance (AL-Sahar et al., 2021).

ii. Drones & Digital imaging

By providing accurate site mapping, structural inspections, and safety surveillance, drones fitted with LiDAR, thermal imaging, and high-resolution cameras drastically cut down on labour expenses and human error (Kong et al., 2019).

iii. IoT sensor and real time monitoring

IoT sensors and AI analytics provide real-time monitoring systems that track energy consumption and waste management, identify structural flaws, improve maintenance, and promote sustainability objectives. Through blockchain-based contract management, AI-driven risk detection, and BIM integration, cloud computing, on the other hand, guarantees smooth collaboration, real-time data exchange, and improved cybersecurity (Arif et al., 2021).

iv. Asset management and smart maintenance

IoT can greatly enhance Asset Management (AM) by providing valuable data, but it requires proper data management to ensure compliance and reliability. Using data for decision-making improves productivity and asset returns (Attencia et al., 2022). The ISO 55000 standards guide AM, focusing on efficiently managing assets like buildings and infrastructure to create value while balancing risks and costs (Rampini et al., 2022).

v. Building automation and energy efficiency

By adopting IoT-enabled innovations, the construction sector can attain previously unheard-of levels of

sustainability, safety, and efficiency, influencing the direction of smart, connected, and data-driven construction in the future (Kumar et al., 2021). It contributes to cost reduction, waste reduction, and even integration of renewable energy sources like solar power. Long-term advantages like cheaper costs and a smaller environmental impact make it a game-changer for contemporary construction, despite obstacles like cost and security.

vi. Digital communication and data management.

IoT enhances digital communication in the construction industry by facilitating real-time data transmission via sensors, smart devices, and cloud computing, which improves project monitoring and cooperation. But handling massive amounts of data created by the Internet of Things has problems with integration with current systems, security, and storage. By facilitating safe remote data access, resource optimization, and predictive maintenance, AI, machine learning, and cloud platforms aid in resolving these problems (Tuhaise et al., 2023).

Small and medium-sized contractor transition towards Construction 4.0

The transition to Construction 4.0 presents significant obstacles for small and medium-sized contractors as a result of financial constraints, technological limitations, and organizational challenges. Key challenges include a general reluctance to implement emerging technologies, high initial investment costs, and a lack of financial resources (Chidiebere et al., 2021). The absence of defined change strategies and inadequate risk management, particularly in the context of cybersecurity, further impedes progress (El Jazzar et al., 2021). Human resource challenges, including a scarcity of skilled labour, unequal access to training, and inadequate awareness of digital tools, exacerbate the issue. In addition, the sector is plagued by a lack of standardization, inadequate legislative support, and a misunderstanding of system integration. The adoption of digital technologies is further delayed by organizational resistance and the industry's gradual cultural transition in comparison to manufacturing (Ratana Singaram et al., 2023). In order to facilitate the successful digital transformation of small and medium-sized contractors in the construction industry, these factors collectively emphasize the necessity of strategic planning, policy intervention, and targeted support.

Strategies for Digitalization in the Malaysian Construction Sector

This study identified that the tactics employed in the business consist of two components: management and construction site operations. Despite Malaysia's push towards digital transformation in construction, several barriers hinder the adoption of IoT in construction 4.0, particularly for small and medium-sized contractors. The key challenge includes organizational resistance, skill shortfalls, policy constraints, and integration issues at project level. A major hurdle is the lack of tech-savvy workers and insufficient IoT training, limiting the industry's ability to adopt smart technologies effectively (Musarat et al., 2024). Arif (2021) stated that high implementation cost, regulatory uncertainties and cybersecurity risk further restricts smaller contractors from fully integrate IoT solution. Additionally, fragmented workflows and the absence standardized IoT protocols create difficulties in seamless integration (Zulkifli et al., 2023). Beyond the challenges in adoption, a smooth transition to IoT is essential to unlock its full potential. Therefore, a framework that guides small-medium sized contractors in adopting IoT is crucial.

c. Conceptual Framework

The conceptual framework, as shown in Figure 1.0 focuses on the implementation of IoT in small medium-sized contractors emphasizing the challenges that hinder adoption, and the strategies needed to facilitate its integration. This framework is developed based on insight from previous research in IoT adoption in construction (Dosumu et al., 2023; Jaafar et al., 2024; Tanko et al., 2023). At the center of the framework is *IoT implementation among small and medium-sized contractors* which represents the adoption and operationalization of IoT technologies in construction projects. Smart sensors, real-time monitoring systems, and automated data collection tools are examples of IoT technologies in construction that enhance productivity, resource management, and site safety. The figure also shows *Challenges* and *Strategies* as important component of the framework. As identified in prior studies, the key challenges include high initial costs, lack of technical expertise, resistance to change, poor network connectivity, and concerns about cybersecurity which makes investing in digital transformation challenging (Shaharudiin et. al, 2021; Ratana Singaram et al., 2023). To enhance the IoT adoption among contractors, strategies as highlighted in previous research such as producing expert workers in digitalization field and improved the quality and consistency of the project are important. It involves management and construction site aspect (Tayib et al., 2022; Arif et al., 2021). Overall, this framework provides a structured overview of how IoT implementation among small and medium-sized contractors can be improved through understanding of the challenges and strategies as previously discussed.

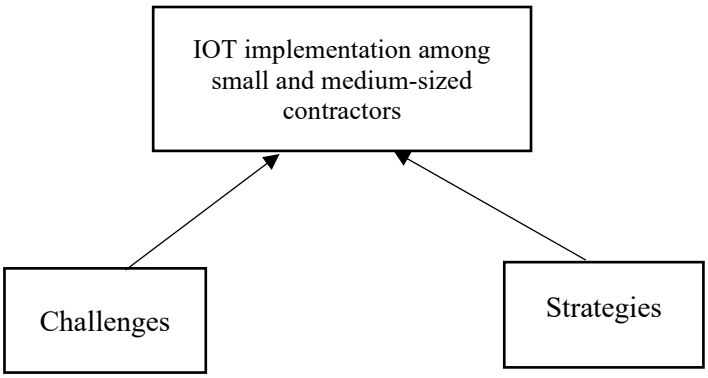


Figure 1.0 Framework for IoT implementation

III.RESEARCH METHODOLOGY

This study adopts a conceptual approach to investigate the implementation of IoT among small and medium sized contractors in Penang. Given the limited research addressing the operationalization of IoT within this sector (Dosumu et al., 2023; Jaafar et al., 2024; Tanko et al., 2023), this paper synthesizes insight from existing literature to identify key challenges and strategies necessary for IoT adoption. It serves as a descriptive model outlining the implementation aspects, associated challenges and strategies for IoT integration without establishing direct causal relationship between these components. A total of 20 peer-reviewed articles published between 2019 and 2025 were reviewed, with sources drawn from Scopus and Google Scholar to ensure academic credibility and reliability. The selected literature focuses on technological advancement in the construction industry, incorporating studies that address relevant keywords such as challenges and strategies that align with objectives of this research. Future empirical research will be conducted to validate and refine the proposed components of the model.

CONCLUSION

The adoption of IoT in construction industry, particularly among small and medium sized contractors, presents both opportunities and challenges. While IoT technologies offer significant advantages, their implementation is often hindered by various challenges. This conceptual paper has developed a descriptive framework to illustrate the key components of IoT adoptions, including implementation aspects, challenges and strategies. This framework serves as structured reference for further empirical investigation into the status of IoT adoption among Malaysian small and medium-sized contractors. The theoretical foundation established in this study also contributes to the continuing discussion on digital transformation in construction, offering insight for industry stakeholders and future research to explore the practical implementation of IoT in the sector.

ACKNOWLEDGMENT

The authors express their sincere gratitude to the School of Housing, Building and Planning (HBP), Universiti Sains Malaysia for funding this publication.

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INTEGRATING INTERNET OF THINGS (IOT) TECHNOLOGY ADAPTATION FOR SMART WASTE MANAGEMENT SYSTEM IN PENANG

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ABSTRACT

Penang's rapid growth in waste generation, combined with the inefficiency of traditional waste management methods such as landfill and incineration, poses significant environmental and operational challenges, leading to sustainability issues and prompting the need for innovative solutions. Japan has successfully implemented a Smart Waste Management System (SWMS), integrating Internet of Things (IoT) technology to optimise waste collection, improve recycling efficiency and reduce environmental impact. However, the feasibility of adopting such systems in Malaysia remains uncertain due to infrastructural, regulatory and socio-economic differences. The objective of this research is to assess the potential of adopting the Japanese SWMS system in Penang by identifying the key challenges, assessing the associated risks and proposing strategies for successful implementation. This research adopts a comparative case study approach that combines both qualitative and quantitative methods. Data were collected through field observations, surveys and expert interviews with officials of the Penang Municipal Council (Majlis Bandaraya Pulau Pinang, MBPP) to gain insights into waste management issues in Penang. In addition, a SWOT analysis was conducted to examine the strengths, weaknesses, opportunities and threats of integrating smart waste technologies in the local environment. It is expected that the outcome of the research will highlight the main barriers and possible strategies for the adoption of SWMS in Penang, providing insights for policymakers and stakeholders to advance sustainable waste management solutions.

Keywords: Smart Waste Management Systems; IoT-Based Waste Management; Waste Management Challenges; Sustainable Waste Solutions; Japan Waste Management Model; Penang Waste Management.

I. INTRODUCTION

Recently, rapid urbanisation and population growth in Malaysia have led to a surge in waste production, creating a major obstacle to effective waste management. According to the Malaysian Ministry of Environment, Malaysia generates an average of 39,078 tonnes of solid waste per day. This situation ultimately leads to overflowing landfills, increased environmental pollution and escalating public health problems. Improper disposal can directly affect the urban environment by causing air, water and soil pollution, leading to long-term health impacts, which in turn indirectly affects our economy and growth opportunities as stated by Himadri Nath Saha and Supratim Auddy. Traditional waste management methods, often characterised by inefficient collection and limited recycling, fail to address these critical issues.

Penang, a key state in Malaysia, exemplifies these challenges. The island generates substantial waste daily but struggles with outdated collection systems and low recycling rates. As part of its Penang 2030 vision, which aims to transform the state into a smart city, local authorities have begun exploring innovative solutions to enhance waste management. One notable initiative is the implementation of smart waste management systems that utilize Internet of Things (IoT) technologies. Owing to a paradigm shift toward Internet of Things (IoT), researches into IoT services are conducted in a very big selection of fields. As a significant application field of IoT, waste management has become one such issue (Himadri Nath Saha & Supratim Auddy). These systems can monitor

waste levels in real time, optimize collection routes and improve communication between waste management authorities and residents.

This research aims to study the potential of smart waste management systems adaption on reduction of waste production in Penang. Through a detailed case study approach, we will analyse the existing implementation of these technologies in Penang's urban environment and examine their effectiveness in improving waste collection efficiency. In addition, this research will explore the challenges of adopting smart systems and make recommendations to overcome these barriers.

By highlighting the potential benefits and challenges associated with technology-driven waste management solutions in Penang, this research aims to provide valuable insights that will inform policy makers, practitioners and stakeholders in their efforts to create more sustainable waste management practices. Ultimately, this project hopes to demonstrate how technological advances can be utilised to improve waste minimisation and environmental management in Malaysia significantly.

1.1 Literature Review

1.1.1 Background of waste management systems in Malaysia

Malaysia faces substantial challenges in managing municipal solid waste (MSW) due to rapid urbanization, industrialization, and population growth, which has resulted in waste generation rates of approximately 0.85 kg per person per day in urban areas stated by Zainu *et al.* and Muin, 2018. The country generates over 38,000 metric tonnes of waste daily, of which only 17.5% is recycled, with the remainder disposed of through landfills, a method that contributes to environmental pollution and greenhouse gas emissions according to Amran *et al*..

The composition of Malaysian municipal solid waste (MSW) has a large proportion of organic waste (estimated to be about 50 %), resulting in high moisture content and making waste treatment less efficient as stated by Omran *et al*.. The high proportion of organic waste, coupled with limited infrastructure such as inadequate recycling facilities and reduced landfill space, creates an urgent need for alternative and sustainable waste management strategies as mentioned by Zainu *et al.* and Muin.

Initiatives to address these challenges include the implementation of the Solid Waste and Public Cleaning Management Act of 2007, which centralises responsibility for waste management and highlights recycling initiatives such as the 3R (Reduce, Reuse, Recycle) scheme. However, these initiatives have had limited success due to low public participation and lack of integrated systems as stated by Zainu *et al.*. Lack of public awareness and participation remain key barriers to the effective implementation of waste management policies (Amran *et al.)*.

Recognising these limitations, the adoption of a Smart Waste Management System (SWMS), which integrates IoT technology to enhance waste collection, monitoring and treatment, has gained increasing attention. Smart waste management systems can help Malaysia address waste management inefficiencies and align with its broader sustainable development goals according to Zainu *et al*..

1.1.2 Land Use Challenges in Penang Affecting Waste Management

Penang faces significant land use challenges that directly affect the efficiency and sustainability of its waste management system. Rapid urbanisation and economic development have led to increased competition for land between residential, commercial, industrial and infrastructure needs, leaving limited space for new waste management facilities or landfill expansion (Raffay et al., 2025). Penang's main waste disposal site, Pulau Burung Landfill, is nearing capacity, and the choice of alternative sites is constrained by environmental sensitivity and encroachment into development areas (Yusof et al., 2023). Inadequate integration of waste infrastructure in urban planning has also led to spatial inefficiencies in implementing advanced solutions such as waste-to-energy plants or smart recycling centres. These land scarcity issues highlight the urgency of adopting spatially efficient smart waste management technologies that reduce reliance on landfills while aligning with Penang's broader urban sustainability goals (Raffay et al., 2025; Yusof et al., 2023).

1.1.3 Importance of smart waste management systems

Smart Waste Management Systems (SWMS) are advanced frameworks for optimising waste collection, transport and disposal using technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) and data analytics. IoT sensors monitor the amount of waste in bins, while algorithm-based AI analyses data to optimise routes and

predict waste generation patterns. For example, IoT sensors integrated into bins notify waste collection teams when bins are full, preventing overflow and reducing unnecessary journeys.. In addition, deep learning algorithms can enhance waste segregation, increase recycling efficiency, and promote a circular economy.

The main advantages of SWMS include the dynamic adjustment of collection routes based on real-time data, which improves the efficiency of waste collection and thus reduces fuel consumption and associated emissions. Cost reduction through optimised scheduling and predictive maintenance of equipment is another major benefit. In addition, SWMS minimises environmental impacts by reducing landfill use, increasing recycling rates and preventing problems such as contamination from overflowing bins.

Success stories from developed countries highlight the transformative potential of smart waste management systems (SWMS). Japan's use of advanced IoT waste management technologies to optimise waste segregation, collection and recycling processes is a good example. For example, Tokyo's Smart Waste Programme uses sensor-equipped IoT bins to monitor waste levels in real time, enabling efficient route planning for waste collection trucks. This reduces operating costs and emissions while increasing recycling rates (Sosunova *et al.,*).

These advances in Japan highlight the potential for Malaysia to adopt similar technologies, aligning with the research goal of exploring and implementing effective SWMS solutions. Malaysia can address its pressing waste management challenges by utilizing IoT systems tailored to local conditions while advancing its smart city goals.

1.1.4 Indicators of challenges in adapting smart waste management systems

Adapting a Smart Waste Management System (SWMS) involves addressing social, financial, technological, and infrastructural challenges. Public acceptance and awareness are critical barriers, as many communities may resist adopting SWMS due to a limited understanding of its benefits or concerns about the changes required in waste segregation habits. To overcome this resistance and foster cooperation, effective education campaigns and public engagement initiatives are necessary (M. A. Rahman et al.). Additionally, the high initial cost of infrastructure, such as IoT sensors and smart bins, presents a significant financial challenge. Developing economies may struggle to justify these expenses while addressing other pressing needs. Therefore, long-term cost savings from operational efficiencies must be carefully evaluated to offset these upfront investments (M. P. Varghese et al.).

Technological challenges also arise due to the compatibility and scalability issues of IoT systems. Many existing waste treatment infrastructures lack integration capabilities, making seamless upgrades difficult. Moreover, inaccurate real-time data from IoT devices and potential communication failures can compromise system reliability (M. A. Rahman et al.). Infrastructural challenges further complicate the implementation of SWMS. As highlighted by Hasan et al., IoT-based systems require a robust network infrastructure, including reliable internet connectivity and power supplies, which may be inconsistent in certain regions. The deployment of smart bins and sensors also necessitates significant upgrades to existing waste collection frameworks, often incurring high installation and maintenance costs. These infrastructural demands can hinder the scalability of SWMS in both urban and rural areas.

1.1.5 Global best practices: Japan as a benchmark

Japan’s waste management system is widely regarded as a global benchmark, particularly due to its emphasis on the 3Rs (Reduce, Reuse, Recycle) and its successful integration of IoT technologies. Smart systems in Japan allow for real-time monitoring of waste levels, optimizing collection routes, and ensuring effective recycling processes (Moshkal & Ogihara). These practices have significantly reduced landfill dependency and improved resource efficiency. Adapting these strategies to Malaysia requires addressing contextual differences, such as socio-economic conditions and public attitudes toward waste segregation.

1.2 Methodology

The methodology of this research aims to provide a comprehensive assessment of the effectiveness and challenges of implementing a smart waste management system in Penang, Malaysia, with a focus on adapting the strategy in Japan. This study adopted a mixed-method approach, combining qualitative and quantitative techniques to gather comprehensive data on the current waste management practices in Penang and to assess the feasibility of implementing an IoT-based Smart Waste Management System (SWMS). The methodology was structured into three systematic stages, with each data collection method contributing directly to the analysis and development of the proposed framework.

Table 1: Summary of Data Collection Methods, Purposes, Analysis Methods, and Outcome Contributions

Method	Purpose	Analysis Method	Outcome Contribution
Field Observations	Assess operational issues & public behavior	Qualitative summary	Weaknesses & threats for SWOT, system gaps for the framework
Public Surveys	Understand public awareness & acceptance	Descriptive statistics	Opportunities & challenges for SWOT, public strategy in the framework
Expert Interviews	Obtain technical & policy insights	Thematic analysis	Technical feasibility, policy, and operational recommendations
SWOT Analysis	Consolidate all primary data	Strategic analysis	Basis for framework structure & recommendations

1.2.1 Data Collection Methods

This study involved both primary and secondary data collection methods to gather comprehensive information on current waste management practices in Penang, to assess public perceptions and readiness, and to gain expert insights to develop a proposal for an IoT-based smart waste management framework. The purpose of the data collection was to ensure a balanced combination of business, social and policy perspectives, which were subsequently integrated through SWOT analysis and framework development.

1.2.1.1 Primary data collection

- *Field Observations:*
  Field observations were conducted at various waste collection points in residential, commercial and public areas of Penang city. The purpose of these observations was to gain a first-hand understanding of existing waste management practices in the field and to identify practical operational issues that could potentially be improved through smart waste management solutions. Specific parameters observed included waste sorting and separation processes, collection frequency, bin overflows and waste spillage, public handling behaviour and the environmental impact of improper waste disposal. Observations provided first-hand evidence of deficiencies in operational practices and system responsiveness, which were then analysed qualitatively and directly helped to identify deficiencies and threats in the SWOT analysis.
- *Surveys:*
  An online survey was conducted with Penang residents via Google Forms to assess their awareness, perceptions and attitudes towards smart waste management initiatives. The questionnaire was designed to assess several important and critical aspects, including the public's current level of knowledge about IoT-based waste management systems, willingness to adopt the new technology, perceived benefits, potential concerns, and suggestions for improvements to existing waste management systems. Responses were compiled and analysed using descriptive statistics to quantify public readiness, acceptance and overall sentiment towards the proposed ITS. The survey results informed the Opportunities and Challenges section of the SWOT analysis, which is essential for designing an effective public engagement strategy within the proposed framework.
- *Expect Interview:*
  Semi-structured interviews were conducted with field professionals and officers from Majlis Bandaraya Pulau Pinang (MBPP) to obtain expert insights into the operational, technical, policy, and financial aspects of waste management in Penang. The interviews focused on understanding MBPP's role in managing the city's waste system, identifying current operational challenges, assessing the feasibility of adopting smart waste management technologies, and exploring policy and regulatory factors that could influence the success of such implementations. Additionally, the discussions included the officers' views on adapting Japan's smart waste management model to the local context and solicited recommendations for future policy improvements and public awareness initiatives. Thematic analysis was applied to the interview transcripts to identify recurring themes, challenges, and expert recommendations, which subsequently contributed to the technical, operational, and policy strategies proposed within the final framework.

1.2.1.2 Secondary data collection

To support the findings from primary data, secondary data collection was conducted through three main sources: literature review, government reports and statistical data, and relevant case study reviews. These secondary resources provided essential contextual information, global best practices, and baseline data for comparison but did not directly contribute to the SWOT analysis outcomes.

- *Literature Review:*
  A comprehensive literature review was conducted to build the theoretical framework and background for this study. This involved reviewing academic journals, conference papers, and scholarly articles related to smart waste management systems, the Internet of Things (IoT) in municipal services, and current trends in global waste management practices. The literature provided insights into operational models, public participation strategies, technological innovations, and policy frameworks from other regions. These references shaped the scope of the research and guided the selection of appropriate primary data collection techniques.
- *Statistical Reports and Historical Data:*
  Official reports and statistical records were obtained from relevant Malaysian government agencies, including SWCorp Malaysia, Majlis Bandaraya Pulau Pinang (MBPP) and the Department of Statistics Malaysia. These data include historical records of waste generation, recycling rates and waste collection performance in Penang. These quantitative records provide supporting evidence to help provide a background analysis of data findings and identify gaps in the operation of the current waste management system.
- *Case Studies:*
  A review of Japan's advanced Smart Waste Management Systems (SWMS) was conducted to identify key practices and technological applications that have been successfully implemented in an urban context. The insights gained from Japan's model served as a conceptual reference in formulating the SWOT analysis and designing the proposed framework for Penang, focusing on features such as IoT-based smart bins, centralized monitoring, and public participation initiatives.

1.2.2 Research framework

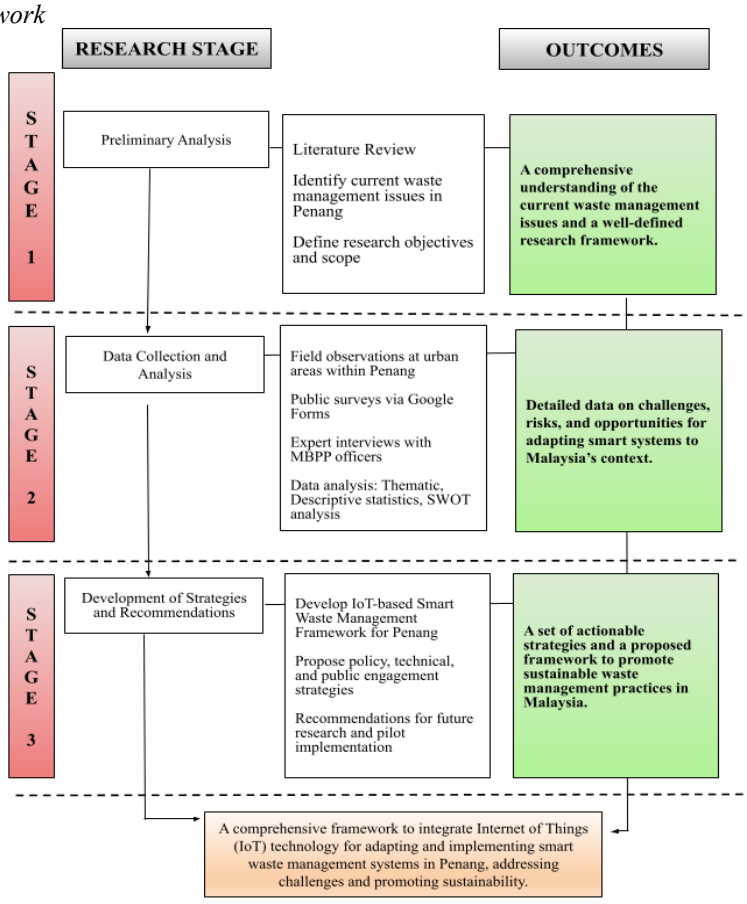


Figure 1: Research Framework for the Potential Implementation of Smart Waste Management Systems (SWMS) in Penang.

The research framework in Figure 1 outlines the systematic process undertaken to assess the potential of integrating Internet of Things (IoT)-based Smart Waste Management Systems (SWMS) in Penang. The framework is structured into three distinct stages, each with specific activities and expected outcomes, leading to a proposed framework for sustainable waste management practices in Malaysia.

The first stage involves conducting a comprehensive literature review to gain insights into global waste management practices and the application of IoT technologies in this field. This stage also includes identifying the current waste management issues faced by Penang, which serves as the foundation for defining the research objectives and scope. The main outcome of this stage is a comprehensive understanding of the existing waste management challenges in Penang and a clear research framework to guide the subsequent stages.

The second stage focuses on gathering both qualitative and quantitative data through various primary and secondary methods. Field observations were carried out at selected urban areas within Penang to examine current waste collection practices and public behavior. Additionally, public surveys were disseminated using Google Forms to assess residents' awareness and willingness to adopt smart waste management systems. Expert interviews with officers from Majlis Bandaraya Pulau Pinang (MBPP) were conducted to gain professional insights into policy, technical, and operational challenges. The collected data were then analyzed using thematic analysis for qualitative data, descriptive statistics for survey responses, and SWOT analysis to assess the strengths, weaknesses, opportunities, and threats of implementing SWMS in Penang. The outcome of this stage is detailed data highlighting the challenges, risks, and opportunities associated with adapting smart waste systems to Malaysia’s urban environment.

The third stage focuses on synthesizing the findings from the data analysis phase to develop a practical framework for IoT-based Smart Waste Management Systems in Penang. This includes proposing actionable strategies in three key areas: policy formulation, technical system development, and public engagement initiatives. Furthermore, recommendations for future research and pilot project implementation are suggested to support the gradual scaling of smart waste systems. The primary outcome of this stage is a set of actionable strategies and a proposed framework designed to promote sustainable, data-driven waste management practices tailored to Malaysia's socio-economic and infrastructural context.

The culmination of this research is a comprehensive framework aimed at integrating IoT technologies for the adaptation and implementation of smart waste management systems in Penang.This framework can address operational challenges, promote environmental sustainability and provide guidance for future technological advancements in urban waste management practices in Malaysia.

2.0 Field Observation Findings

Field observations were conducted in several urban areas of Penang, focusing on residential neighbourhoods, commercial areas and public waste collection points. The objective was to directly assess current waste management practices, identify operational inefficiencies and assess the potential benefits of integrating an IoT-based Smart Waste Management System (SWMS). Potential benefits of an IoT-based Smart Waste Management System (SWMS).

It was observed that waste segregation at source was poorly practiced by both residents and commersials. In most areas, general waste, recyclables, and organic waste were disposed of together in the same bins. Although recycling bins were available at selected public locations, they were underutilized, and signage promoting proper segregation was either unclear or absent. Besides, overflowing bins were a common issue, especially in high-density residential areas and commercial districts during weekends, public holidays, and festive seasons. Waste collection schedules appeared to be fixed and not responsive to actual bin capacity levels. This led to unsightly waste overflow, foul odors, and increased risk of pest infestations in affected areas.

Informal conversations with residents and commercial owners revealed limited awareness of smart waste management technologies. While most participants expressed dissatisfaction with the current system, only a minority were familiar with IoT-based solutions or interested in adopting new waste disposal practices. There was a clear need for awareness campaigns and educational programs to promote public cooperation in future smart waste initiatives. In several locations, accumulated waste due to delayed collection resulted in negative environmental conditions, including bad odors, visual pollution, and the attraction of stray animals such as cats and rats. In certain cases, waste overflow blocked pedestrian walkways, posing public health and safety concerns for local communities.

The findings from these observations highlight significant inefficiencies in Penang's current waste management system and emphasize the urgent need for a responsive, data-driven solution. These insights provide direct support for the SWOT analysis and form the empirical basis for developing the proposed IoT-based Smart Waste Management Framework.

3.0 Proposed Framework for IoT-Based Smart Waste Management System (SWMS) in Penang

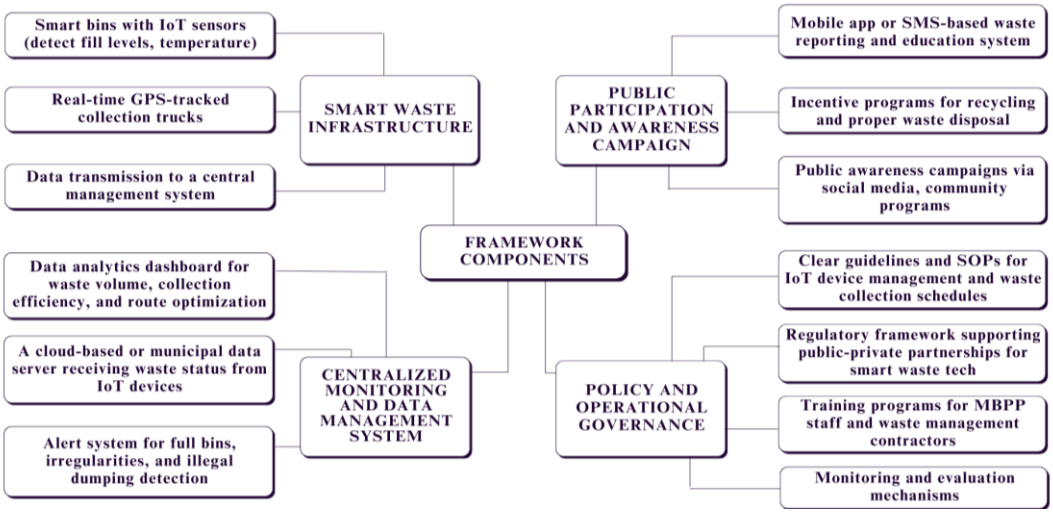


Figure 2: Four Main Components of IoT-Based Smart Waste Management System

Table 2: Framework Process Flow of IoT-Based Smart Waste Management System

Input	Process	Output
Data from smart bins, trucks	Data transmission, analysis, and routing decisions	Optimized collection routes, efficient waste handling
Public reports via app	Integration into management system for alerts and updates	Quick response to issues, increased public engagement
Policies, guidelines, expert input	Framework for operational and technical standards	Sustainable and scalable smart waste management model

This proposed framework integrates IoT technology, centralized data management, community participation, and regulatory governance to enhance Penang's waste management system. Smart bins equipped with fill-level and temperature sensors collect real-time data on waste volume and status. These data points are transmitted via a cloud-based monitoring system, where waste collection schedules and truck routes are optimized based on fill levels and traffic conditions.

The framework emphasizes public participation through a mobile application and SMS-based reporting, enabling residents to report issues, receive updates, and access educational content about waste management. Incentive programs and public awareness campaigns further encourage responsible waste practices.

At the governance level, the framework recommends clear operational guidelines, standard operating procedures, and a policy framework that supports the implementation of smart waste management technology. It also highlights the importance of training waste management personnel and continuous monitoring to ensure system effectiveness. This integrated approach aims to reduce operational inefficiencies, increase recycling rates, and improve overall public hygiene in Penang.

CONCLUSION

This research assesses the potential of adapting Japan's Smart Waste Management System (SWMS) in Penang by examining the challenges, risks, and strategies required for successful implementation. The findings reveal that the challenges in implementing SWMS include infrastructural limitations, financial constraints, policy gaps, and low public awareness, aligning with the first research objective. Addressing these challenges is crucial for ensuring the successful adaptation of advanced waste management practices in Penang.

In addressing the second research objective, the research identifies risks associated with adapting Japan's waste management model to Penang, including technological adaptation barriers, governance inconsistencies, and resistance to behavioral change among the public and stakeholders. The comparative analysis between Japan and Penang highlights significant differences in regulatory frameworks, waste collection efficiency, and public participation, which may affect the feasibility of adaptation. Understanding these differences is essential for tailoring strategies that fit the local context.

To achieve the third research objective, the research proposes strategies to promote and adapt SWMS in Malaysia, emphasizing policy enhancements, increased financial investment in IoT-based waste systems, and public engagement initiatives. These strategies aim to bridge the gap between traditional waste management practices and smart, data-driven solutions, promoting environmental sustainability and operational efficiency.

The research is significant to explore the feasibility of implementing IoT-based smart waste management systems in Penang and also to provide practical recommendations for policymakers, stakeholders, and municipal authorities. The findings contribute to understanding how Japan's advanced practices can be adapted to Penang's local context, offering a foundation for future studies. Additionally, the study serves as a valuable reference for regions in Malaysia or other developing countries that face similar waste management challenges. The proposed strategies have the potential to influence policy reforms, enhance public awareness, and encourage greater investment in sustainable waste management technologies. However, this study faced several limitations, including a relatively small survey sample size and a limited number of observation locations, which may affect the generalizability of the findings. Additionally, while Japan's Smart Waste Management System (SWMS) served as a conceptual benchmark, differences in infrastructure, policy frameworks, and public behavior between Japan and Penang may limit the direct applicability of certain strategies. Future research should consider involving a broader demographic sample and exploring additional urban areas within Malaysia to enhance the comprehensiveness and validity of the proposed framework and it is necessary to assess real-world implementation through pilot projects, evaluate cost-effectiveness, and refine strategies based on local environmental and socio-economic conditions. The successful adaptation of smart waste management systems could set a precedent for sustainable waste management across Southeast Asia, contributing to broader environmental conservation and improved urban living standards.

ACKNOWLEDGMENT

The main author would like to express his gratitude to Building Surveying Department of University Science Malaysia(USM), especially the supervisor for funding this publication.

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EXPLORING THE POTENTIAL APPLICATIONS OF CHATBOT MANAGEMENT SYSTEMS FOR CONSTRUCTION FIRMS: FROM MANAGERIAL PERSPECTIVES

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ABSTRACT

The construction industry faces persistent challenges in communication, project coordination, and managerial decision making, leading to inefficiencies such as cost overruns and project delays. While digital transformation has improved operations in various industries, the integration of Chatbot Management Systems (CMS) in construction firms remains underexplored. This research addresses this gap by investigating the potential applications of CMS in construction management from a managerial perspective. The study aims to identify factors influencing the adoption of CMS, evaluate their benefits in human resource management, and develop a strategic framework for implementation. A quantitative approach was employed, utilizing structured surveys distributed to construction professionals in Klang Valley, Malaysia. The collected data were analysed using statistical methods to assess the impact of CMS on project efficiency and decision-making. Key findings indicate that CMS significantly enhance managerial efficiency by automating administrative tasks, improving communication among stakeholders, and streamlining project workflows. The study reveals that chatbot integration can reduce scheduling errors, enhance risk identification, and facilitate real time information sharing, leading to improved project execution. However, challenges such as system integration, employee resistance, and data security concerns must be addressed to maximize CMS adoption. The findings highlight the transformative potential of CMS in construction management, offering a roadmap for firms seeking to leverage AI powered solutions. By addressing managerial challenges and enhancing operational efficiency, CMS can play a pivotal role in modernizing construction project management. This research contributes to the growing discourse on AI applications in construction and provides valuable insights for industry professionals and policymakers.

Keywords: Chatbot Management Systems, Construction Industry, Artificial Intelligence, Managerial Efficiency, Digital Transformation.

I. INTRODUCTION

Chatbot Management Systems (CMS) are transforming industries by improving efficiency and user engagement. These AI-driven tools streamline customer service, automate tasks, and support decision-making through natural language processing (Karchi et al., 2023; Albeshr et al., 2024). In construction, complex challenges such as project delays, communication gaps, and cost overruns demand innovative solutions (Rehan et al., 2024). AI-powered chatbots offer significant potential to enhance project management by automating administrative tasks, improving risk identification, and optimizing resource allocation (Alhasan & Alawadhi, 2024). However, successful integration requires addressing challenges like data security and standardization (Parekh & Mitchell, 2024). This research explores the managerial applications of chatbots in construction to enhance efficiency and stakeholder coordination.

II. BACKGROUND OF THE STUDY

The construction industry faces ongoing challenges in project management, communication, and resource coordination, often leading to delays and cost overruns (Charan & Vaardini, 2024; Basar & Basar, 2023). Miscommunication, stakeholder conflicts, and labor shortages further complicate operations (Rehan et al., 2024). To address these issues, firms are adopting technologies like BIM, cloud-based platforms, AI, and automation to enhance collaboration, efficiency, and safety (AJAYI et al., 2024; Silitonga & Jin, 2024).

Chatbot systems, successfully used in banking, healthcare, and education, offer promising applications in construction. They can automate administrative tasks, improve communication, assist in risk management, and enhance worker

training (Cho & Lee, 2019; Lin, 2023). Integrating chatbots with existing digital tools like BIM can further streamline project workflows. Despite challenges such as data security and user acceptance, chatbot management systems have the potential to improve efficiency, reduce costs, and enhance project execution.

III. PROBLEM STATEMENT

The construction industry faces ongoing challenges in communication, project coordination, task management, and cost control, leading to delays, budget overruns, and stakeholder dissatisfaction (Charan & Vaardini, 2024). Existing project management tools lack integration and real-time adaptability, resulting in inefficient decision-making (K et al., 2020; Homenko et al., 2022). Manual data entry and fragmented systems further contribute to errors and delays (Chen, 2023).

AI-powered chatbots, proven effective in other industries, offer potential solutions by automating tasks, enhancing communication, and supporting real-time decision-making. However, their adoption in construction is limited due to integration challenges, unstructured data handling, and reliance on manual interventions (Cho & Lee, 2019; Lin, 2023). This research explores how chatbot management systems can address these gaps, improving operational efficiency and stakeholder coordination in construction projects.

IV. OBJECTIVE

This study aims to explore how chatbot management systems can transform the construction industry by addressing some of its critical challenges, such as communication barriers, decision-making inefficiencies, and client management.

The objectives are:

1. To identify the influential factors that contribute to the effectiveness of Chatbot Management Systems (CMS) in construction firms.
2. To explore the potential benefits of CMS in the human resource domain, with a specific focus on recruitment and talent acquisition.
3. To develop a strategic framework for the adoption and integration of CMS in managerial practices within construction firms.

V. LITERATURE REVIEW

Related Theories and Models

The adoption of Chatbot Management Systems (CMS) in construction firms can be understood through three key theoretical models which is the Unified Theory of Acceptance and Use of Technology (UTAUT), the Technology Acceptance Model (TAM), and the Diffusion of Innovation (DOI) theory.

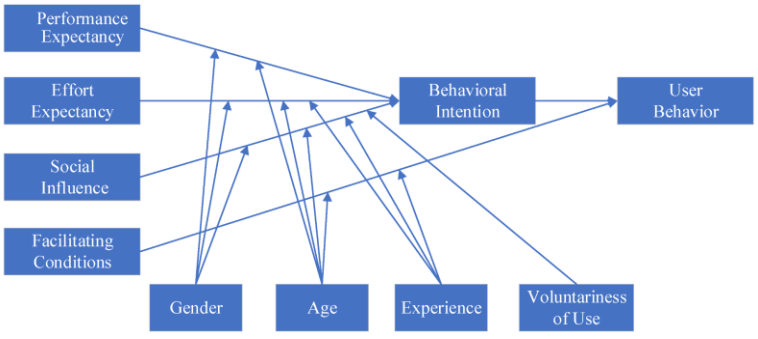


Figure 1: Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT identifies four key factors influencing technology adoption which is performance expectancy (improved job performance), effort expectancy (ease of use), social influence (peer and managerial encouragement), and facilitating conditions (resources and support) (Thanthrige et al., 2024; Bere et al., 2024).

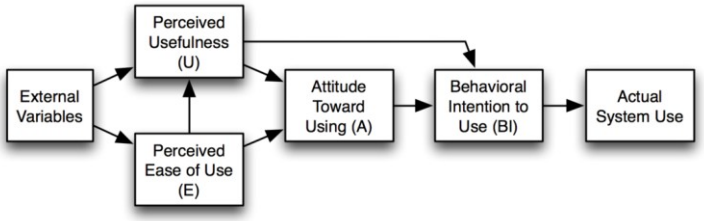


Figure 2: Technology Acceptance Model (TAM)

TAM focuses on perceived ease of use (simplicity of the system) and perceived usefulness (impact on work efficiency), both of which determine user acceptance of technology (Akbarini, 2024; Medina et al., 2024).

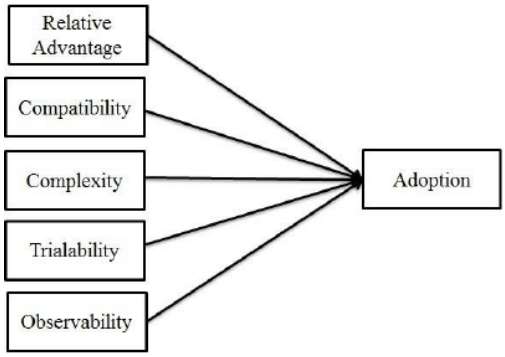


Figure 3: Diffusion of Innovation Theory (Roger, 1983)

The concept of Diffusion of Innovation Theory (DOI) is how innovations spread, categorizing adopters into groups and emphasizing factors such as relative advantage, compatibility, complexity, trialability, and observability in influencing adoption (Yun & Lee, 2024; Chen, 2024).

These models collectively provide insights into CMS adoption, addressing both technological and human factors to enhance implementation and effectiveness in construction firms.

Review of Constructs and Concepts Involved

Chatbot Management Systems (CMS) are AI-powered tools that enhance communication, automate tasks, and provide real-time insights using technologies like Natural Language Processing (NLP) and machine learning (Nze, 2024; Adli et al., 2024). CMS continuously improves through evaluation, learning, and adaptation, ensuring that chatbots remain effective over time (Almeida et al., n.d.). Key components include:

1. User interface for seamless interaction
2. Chatbot engine for query processing
3. Failure management engine for issue resolution (Mok et al., 2019)

In construction, CMS automates scheduling, report generation, and data analysis, allowing managers to focus on complex tasks (Küntzel, 2022; Manju & Jatain, 2023). Key features like API integration, workflow automation, data analytics, and multi-channel management make CMS valuable for decision-making, innovation, and business process automation (Ferreira et al., 2021; Alaaeldin et al., 2021). However, challenges include lack of standardization, ethical concerns, and strategic alignment (Santos et al., 2022; Khneyzer et al., 2024).

CMS enhances communication, task automation, and real-time data management in construction firms. It streamlines interactions among stakeholders, reducing miscommunication (Cho & Lee, 2019). Automation features, such as meeting scheduling and resource tracking, boost efficiency (Tsai et al., 2021). Real-time data processing tools like SafetyBot (hazard detection), MaterialBot (supply tracking), and ClientCare (client support) improve decision-making and collaboration (Nyqvist et al., 2024). CMS ultimately reduces delays, controls costs, and optimizes project performance (Patil et al., 2024; Rane et al., 2024).

Common challenges include miscommunication, project delays, budget overruns, and stakeholder conflicts (Charan & Vaardini, 2024; Rehan et al., 2024). CMS helps by automating updates, clarifying misunderstandings, and providing

accurate real-time data, enabling managers to make confident decisions and improve project outcomes (Lin, 2023).

Adoption Challenges of CMS

1. Legal compliance to ensure CMS meets data privacy and security regulations is crucial to avoid penalties (Patil et al., 2024).
2. Technical integration because many firms use legacy systems that are incompatible with modern CMS, requiring costly upgrades (Dreyling et al., 2024).
3. Organizational resistance such as employees may fear job displacement or struggle to adapt to new technology, requiring clear communication, training, and reassurance (Matveeva, 2022).

Despite these challenges, strategic CMS adoption can maximize efficiency, improve communication, and enhance decision-making, transforming how construction projects are managed.

Review of Past Studies

Research on Chatbot Management Systems (CMS) highlights their ability to improve efficiency, communication, and cost reduction across industries, including healthcare, retail, and construction. While CMS is widely studied, gaps exist in construction project management applications and regional studies, particularly in Malaysia.

I. CMS Applications Across Industries

- Healthcare: AI chatbots reduce administrative tasks by 20%, assist in appointment scheduling, and improve telemedicine accessibility (Nze, 2024; Ismail et al., 2024)
- Retail: CMS enhances customer service, reducing response times by 30% and increasing engagement by 40%, while also lowering operational costs (Nwokedi & Nwafor, 2024; Ismail et al., 2024)
- Construction: AI-driven CMS integrated with Building Information Modeling (BIM) and Natural Language Understanding (NLU) improves site management and reduces scheduling errors by 35% (Lin, 2023; Alhasan & Alawadhi, 2024)

II. Identified Gaps in Literature

- Limited research on CMS tailored for construction project management, particularly in terms of system interoperability and on-site usability
- Lack of regional studies, especially in Malaysia, where factors like regulations, labor dynamics, and technology adoption require further exploration.

III. Impact on Managerial Roles and Project Outcomes

- Enhanced Communication: Chatbots provide immediate responses, reducing delays and improving stakeholder engagement (Cho & Lee, 2019).
- Task Automation: CMS streamlines scheduling and reporting, allowing managers to focus on strategic decision-making (Cīrule & Bērziša, 2019).
- Shifting Managerial Roles: Leaders must adapt to AI-integrated workflows, address employee concerns, and balance human expertise with automation (Nyqvist et al., 2024).

Framework of the Study

Theoretical Framework

This study applies three key theoretical models—Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Diffusion of Innovation (DOI)—to analyze the adoption and effectiveness of Chatbot Management Systems (CMS) in recruitment and talent acquisition within construction firms.

1. Technology Acceptance Model (TAM)

TAM focuses on individual acceptance of CMS, particularly by HR professionals and job applicants, through:

- Perceived Ease of Use (PEOU): How intuitive and user-friendly CMS is for tasks like applicant screening and interview scheduling.
- Perceived Usefulness (PU): The extent to which CMS improves HR efficiency by automating communication, reducing workloads, and enhancing the candidate experience.

2. Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT extends TAM by incorporating organizational and social factors, including:

- Performance Expectancy: The anticipated benefits of CMS, such as faster hiring and better candidate selection.
- Social Influence: The impact of peers and managers in encouraging CMS adoption.
- Facilitating Conditions: Access to training, technical support, and integration with HR tools like applicant tracking systems.

3. Diffusion of Innovation (DOI)

DOI explains how CMS adoption spreads within organizations, emphasizing:

- Relative Advantage: CMS efficiency in comparison to traditional HR methods.
- Compatibility: How well CMS aligns with existing HR processes in construction firms.
- Trialability & Observability: The ability of HR teams to test CMS features and demonstrate benefits to stakeholders.

Conceptual Framework

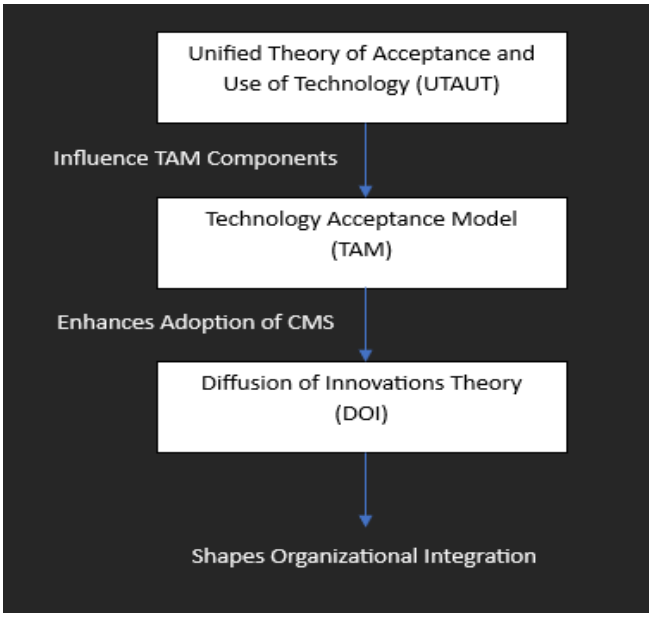


Figure 4: Conceptual Framework

1. Technology Acceptance Model (TAM)

TAM focuses on individual acceptance through:

- Perceived Ease of Use: How simple and intuitive users find CMS.
- Perceived Usefulness: The extent to which CMS enhances efficiency by automating tasks and improving communication.

2. Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT considers organizational and social factors, including:

- Performance Expectancy: How well CMS is expected to improve work efficiency.
- Social Influence: The role of peer and organizational encouragement in adoption.
- Organizational Resources: Training and support that facilitate CMS implementation.

3. Diffusion of Innovations Theory (DOI)

DOI explains how CMS adoption spreads, emphasizing:

- Compatibility: CMS should align with existing tools and workflows.
- Peer Influence: Early adopters encourage widespread use.
- Rate of Adoption: Managing the speed of CMS implementation.

CONCLUSION

In conclusion, the integration of Chatbot Management Systems (CMS) into construction management holds significant promise for addressing persistent inefficiencies such as communication barriers, project delays, and cost overruns. This research highlights the transformative potential of CMS in enhancing managerial efficiency by automating routine administrative tasks, improving stakeholder communication, and streamlining project workflows. The findings suggest that CMS can lead to more accurate scheduling, better risk management, and more effective real-time information sharing, all of which contribute to improved project execution. However, challenges such as system integration, employee resistance, and data security concerns must be carefully

managed to ensure the successful adoption of CMS in construction firms. By overcoming these barriers, construction organizations can leverage AI-driven solutions to modernize their operations, improve decision-making, and ultimately increase project success rates. This study not only contributes valuable insights to the growing body of literature on AI in construction but also provides practical guidance for industry professionals and policymakers seeking to harness the benefits of digital transformation in construction management.

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APPLICATION OF MIXED REALITY (MR) IN TEACHING AND LEARNING OF CONSTRUCTION RELATED COURSES

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ABSTRACT

The rapid advancement of Industry 4.0 has led to the emergence of Construction 4.0, which integrates digital and smart technologies such as Building Information Modelling (BIM), Artificial Intelligence (AI), the Internet of Things (IoT), and immersive tools like Mixed Reality (MR). MR has demonstrated significant potential in enhancing education by providing interactive and immersive learning experiences. However, despite its benefits, the implementation of MR in teaching and learning construction-related courses remains limited. Traditional teaching methods in built environment education primarily rely on passive learning approaches, hindering students' engagement, critical thinking, and readiness for digital transformation. This study investigates the potential and challenges of implementing MR in construction-related education. It explores key barriers such as the underutilization of MR, resistance to adopting new teaching methodologies, and the lack of modern technological integration in universities. While MR offers a dynamic and interactive platform for improving design comprehension, safety training, and collaborative learning, many institutions still rely on conventional lecture-based methods that limit student engagement. Additionally, the absence of adequate MR infrastructure and a lack of specialized knowledge among educators further impede its adoption. By identifying the opportunities and obstacles in MR implementation, this research aims to provide insights into how educational institutions can integrate MR to enhance teaching and learning. The findings will help bridge the gap between traditional teaching practices and digital transformation in construction education. Ultimately, the study emphasizes the need for a paradigm shift in learning methodologies to equip future professionals with essential digital competencies, fostering innovation and efficiency in the construction industry.

Keywords: Mixed Reality, Construction 4.0, Digital Learning, Built Environment Education, Industry 4.0, Teaching Innovation

I. INTRODUCTION

a. Background of Study

Industrial Revolution 4.0 (IR 4.0) forms the basis for Construction 4.0, emphasizing digital technologies like BIM, IoT, AI, robotics, and Mixed Reality (MR) to improve efficiency, collaboration, and innovation in construction (Nechyporchuk et al., 2023; Begić et al., 2022). Malaysia's MyHE4.0, MyDIGITAL and Industry4WRD policies further support this digital transformation by promoting the adoption of emerging technologies across industries, including construction and education. Construction 4.0 supports industry transformation and workforce development through education and training (Forcael et al., 2020). According to CIDB's Construction 4.0 Strategic Plan (2021-2025), integrating technologies such as MR into construction education is crucial to prepare students for evolving industry demands. Additionally, the Malaysia Education Blueprint (Higher Education) 2015-2025 and Higher Education 4.0 emphasize the need for digital learning environments and smart technologies to modernize teaching methods. MR which combines VR and AR, enhances learning by providing immersive, interactive environments that improve skills in design comprehension, safety, and collaboration.

b. Problem Statement

The construction industry is rapidly evolving under the influence of digital transformation, requiring future professionals to possess strong digital competencies. However, construction education in Malaysia continues to lag behind in equipping students with these skills, largely due to the persistent reliance on traditional teaching methods such as lectures, textbooks, and static presentations. This disconnect between education and industry

needs is contributing to a skills gap, leaving graduates underprepared for the demands of the digital construction environment.

Traditional pedagogies are no longer sufficient to simulate the dynamic, spatial, and collaborative nature of construction work. Studies such as Harjana et al., 2023and Pliushch & Sorokun, 2022 have found that conventional teaching methods hinder critical thinking, creativity, and digital fluency—key competencies required in modern construction practices. Furthermore, they limit interactive and experiential learning, making it difficult for students to develop a deeper understanding of construction concepts and site conditions.

Mixed Reality, an advanced immersive technology that blends real and virtual environments, offers a promising solution to these challenges. In construction education, MR can enhance spatial visualization, simulate real-world site conditions, and support interactive, hands-on learning experiences. By enabling students to engage with 3D construction models and environments, MR fosters better comprehension, improved engagement, and greater collaboration between educators and learners.

Despite the growing availability of MR and VR labs in Malaysian universities, their application remains limited to computing and design-based programs (Ghanbaripour et al., 2024). Construction-related programs, in contrast, have yet to fully adopt MR in their teaching practices. This highlights a significant research and implementation gap in the integration of immersive technologies in construction education.

The underutilization of MR, coupled with institutional resistance to innovative teaching methods, hinders students' readiness to meet the demands of the Construction 4.0 era (Zhang et al., 2024; Abouelkhier et al., 2024). If not addressed, this issue could further widen the competency gap between construction graduates and the digital expectations of the industry. Therefore, this study aims to investigate the potential and challenges of MR adoption in construction education, emphasizing the need for a more interactive, digitally aligned teaching approach to better prepare students and educators for the future.

c. Research Aims and Objectives

Based on the recent issues, this study aims find out the potentials and challenges of implementation of Mixed Reality in teaching and learning of construction related courses. In order to achieve the aim of this research, the following research objectives have been set out:

1. To identify the potentials of implementation of Mixed Reality (MR) in teaching and learning of construction-related courses.
2. To identify the challenges of implementation of Mixed Reality (MR) in teaching and learning of construction-related courses.

A comprehensive understanding of the potential and challenges of implementation of MR in teaching and learning of construction-related courses enables the educational institutions to formulate strategic plans, allocate appropriate resources, and design effective curriculum to support the successful integration of MR technologies.

II. LITERATURE REVIEW

The in-depth study of Mixed Reality, its potential and challenges to the teaching and learning of construction-related courses is discussed. This will provide a more comprehensive and better insight of the study. The main objective of this subsection is to provide readers with a basic idea and direction of the topics discussed.

a. Introduction To Mixed Reality

Mixed Reality is a technology that seamlessly integrates the physical and virtual worlds, allowing users to interact with and manipulate both real and digital objects in real time. Unlike Virtual Reality, which fully immerses users in a simulated environment, or Augmented Reality, which overlays digital content onto the real world, MR merges both VR and AR to create an interactive and immersive experience. In Malaysia, the integration of MR is supported by national strategies such as *MyDIGITAL, Industry4WRD, CIDB's Construction 4.0 Strategic Plan*, and *MyHE 4.0*, all of which encourage digital transformation in sectors including higher education. Within the education sector, MR offers immersive learning that enhances engagement, supports practical skill development, and improves spatial understanding. In construction education specifically, MR enables students to interact with Building Information Modelling (BIM), simulate construction sites, and develop the digital competencies required by the industry.

To support these applications, MR systems possess several distinctive features. These include the integration of real and virtual environments, allowing seamless interaction between digital elements and physical surroundings. MR provides immersive 3D content through high-resolution holograms, stereo sound, and spatial audio. Interaction is enabled via natural inputs such as hand gestures, gaze tracking, and voice commands, making MR systems intuitive and user-friendly. Spatial mapping capabilities allow precise placement of virtual elements in real-world settings. MR devices are also lightweight and portable, facilitating flexible use across various environments. Additionally, MR systems can simulate textures and material properties realistically, reduce dependence on physical prototypes, and enhance learning outcomes by presenting information in interactive, spatial formats (Evans et al., 2017; Microsoft, 2024; Osorto Carrasco & Chen, 2021).

b. Types of Mixed Reality (MR)

Table 2.1: Types of Mixed Reality

No.	Type of Mixed Reality (MR)	Descriptions
1	Immersive Mixed Reality	Immersive MR systems seamlessly blend physical and virtual environments, creating highly engaging experiences. Devices like Microsoft HoloLens allow real-time interaction with holographic models while maintaining real-world awareness. Key features include hand tracking, gaze control, and spatial mapping for enhanced user interaction (Rokhsaritalemi et al., 2020).
2	Collaborative Mixed Reality	Collaborative MR enables multiple users to interact with digital objects and each other in real time, regardless of location. It is commonly applied in engineering and construction for virtual project planning and remote risk assessment (Pridhvi et al., 2023).
3	Augmented Virtuality	Augmented Virtuality is a subtype of MR where virtual environments are enhanced with real-world elements, such as live video feeds or physical object representations, within predominantly digital spaces (Rokhsaritalemi et al., 2020); Merino et al., 2020).
4	Spatial Mixed Reality	Spatial MR overlays digital elements onto real-world spaces with precision. In fields like construction and retail, it allows users to visualize 3D models on existing structures for design changes or product placement (Pridhvi et al., 2023).
5	Context-Aware Mixed Reality	Context-aware MR adjusts virtual content based on real-world data such as user location or environment. Common applications include location-based AR games and geotagged interactive content on social media (Pridhvi et al., 2023).
6	Interactive and Analytical Mixed Reality	Interactive and Analytical MR focuses on real-time interaction and analysis. It is used in education and healthcare for tasks like training, surgical planning, and studying complex systems, allowing users to manipulate virtual objects effectively (Pridhvi et al., 2023).

Mixed Reality (MR) encompasses various types, each offering unique capabilities tailored to specific applications. Immersive MR provides fully engaging environments by integrating real and virtual elements, while Collaborative MR supports multi-user interactions across locations. Augmented Virtuality blends physical inputs into digital environments, and Spatial MR precisely overlays digital content onto real-world settings. Context-Aware MR adapts virtual content based on real-world data such as user location, and Interactive and Analytical MR enables real-time manipulation and analysis of virtual objects. Among these, Collaborative MR, Spatial MR, and Context-Aware MR are widely adopted in the construction industry for project planning and site visualization, whereas Immersive MR and Interactive and Analytical MR are particularly valuable in education to enhance engagement, comprehension, and practical skill development.

c. Implementation of Mixed Reality in Education

Mixed Reality has been increasingly adopted in education to enhance students' understanding of abstract and complex subjects such as biology, chemistry, and mathematics. By enabling immersive 3D visualizations and interactive simulations such as viewing molecular structures or conducting virtual experiments, MR improves engagement, facilitates conceptual learning, and reduces physical risks and resource consumption. The integration of MR into mobile devices also supports interactive and collaborative learning environments, overcoming limitations of conventional teaching methods (Yiğit Baba, 2022; Pridhvi Krishna et al., 2018).

d. Teaching and Learning of Construction Related Courses

In the construction field, MR is applied to simulate real-world environments and complex systems, offering students a hands-on learning experience. It allows interaction with digital building models, such as BIM, enabling learners to visualize construction elements, understand spatial relationships, and practice site procedures in a risk-free virtual environment. MR also supports the development of digital competencies, critical for preparing students to meet industry demands for technologically skilled professionals.

e. Potential of Implementation of MR in Teaching and Learning of Construction Related Courses

i. Teaching and Learning Assisting Tools

1. Immersive Educational Tool

Mixed Reality (MR) enhances learning by blending real and virtual environments, allowing students to remain aware of their physical surroundings while interacting with digital elements. This balance creates an immersive, engaging learning experience without the risks of full virtual isolation (Ostanin & Klimchik, 2018).

2. Interactive and Collaborative Learning

MR supports collaborative learning by allowing students to interact in shared virtual and physical spaces. It also improves student-teacher communication, enabling teachers to observe nonverbal cues and assess engagement effectively (Ogunseiju et al., 2022). This real-world connection prevents student isolation and aids in monitoring progress.

3. Skill Development in Construction Education

MR as a pedagogical tool emphasizes learnability, efficiency, and user satisfaction in construction education. By incorporating interactive elements like game objects, it supports cognitive apprenticeship theory and helps students develop specialized skills, such as laser scanning, while addressing real-world construction challenges (Ogunseiju et al., 2022).

4. Real-World Learning Integration

MR technology enhances real-world learning by providing practical, hands-on experiences. It allows students to visualize complex construction processes, bridging the gap between theoretical knowledge and industry practices through interactive digital representations.

5. Enhancing Learning Outcomes in Construction Education

Mixed Reality (MR) is a transformative tool in construction education, enhancing engagement and motivation by delivering spatial information interactively. Integration with BIM creates enriched learning environments, helping students grasp complex design concepts and effectively transfer skills to real-world construction tasks (Vasilevski & Birt, 2020) (W. Wu et al., 2018).

MR-based learning environments promote active learning, better communication, and deeper understanding of complex concepts. Studies show MR improves learning outcomes by offering immersive, real-time practice opportunities (W. Wu et al., 2018). Moreover, MR mock-ups effectively train both students and professionals, helping bridge the skills gap in construction education and preparing students to meet industry demands.

ii. Practical and Training System

Mixed Reality (MR) provides a powerful platform for practical training by simulating real-world construction environments. It allows students to gain hands-on experience and develop essential construction skills, including the application of sensing technologies (Ogunseiju et al., 2021).Moreover, MR-based simulations also enhance understanding of construction sequences and improving practical abilities (Abouelkhier et al., 2024).

Additionally, MR improves safety training by replicating site conditions, enabling safe machinery operation practice (Frédéric Bosché et al., 2015). MR also further enhances design communication through direct

visualization of building systems like BIM layouts, offering greater efficiency than traditional methods (Chalhoub & Ayer, 2018).

iii. Laboratory and Studio Work Assisting Tools

In laboratory and studio settings, MR offers immersive, interactive experiences that allow students to visualize and interact with digital twins of construction projects, improving their understanding of complex systems like HVAC, electrical layouts, and structural elements (Tayeh et al., 2021). It enhances spatial awareness and problem-solving by providing realistic 3D environments. MR also simulates hazardous conditions, enabling students to practice safety skills in a risk-free setting (L. Zhang et al., 2024a).

Additionally, MR enhances presentation tools by enabling interactive visualization of construction projects. Its integration with BIM and GIS improves communication and collaboration among students, instructors, and industry stakeholders, facilitating better project understanding (Tayeh et al., 2021).

iv. Help Low Vision Students in Learning

Mixed Reality (MR) can support low vision students by providing customizable visual aids and interactive content tailored to their needs. Devices like Microsoft HoloLens enhance the visual field for users with impaired vision through overlays and immersive 3D environments, while Magic Leap offers similar customizable features (Ke et al., 2016a). These technologies promote inclusive learning by offering alternative ways for students to access and interact with educational content.

f. Challenges of Implementation of MR in Teaching and Learning of Construction Related Courses

v. Financial Aspect

Implementing Mixed Reality (MR) in education involves significant financial challenges due to the high costs of hardware, software, and maintenance. Devices like Microsoft HoloLens and Magic Leap can cost up from RM14.000, excluding the additional expense of high-performance computers needed for smooth operation. Developing MR-specific software also requires specialist expertise, adding to the cost. Institutions face further expenses in establishing MR labs and maintaining equipment, making resource allocation for effective MR integration difficult (Vasilevski & Birt, 2020) (Abouelkhier et al., 2024).

Table 2.2 Price and Function of MR Devices

MR Headset	**Microsoft HoloLens**	**Magic Leap**	**Meta Quest Pro**
Headset Price	RM14K (TechNave, 2019.)	RM15K	RM8K (PriceMe, 2023)
Additional Cost	MR-capable Computer		
Pixel Resolution	2K resolution	1280 x 960	1800 x 1920 per eye
Degrees of Freedom	6 (Pitch, Yaw, Roll, Elevating, Strafing, Walking)		
Weight	20.5 oz	21 oz	22.93 oz
Tracking	Head, Two Hands		Head, Eye, Hands

vi. Training of Lecturers

Training lecturers to effectively use Mixed Reality (MR) is crucial for successful integration into teaching. Educators must understand both MR's technical aspects and its educational applications (Ke et al., 2016) (Tayeh et al., 2021). However, continuous training requires significant time and financial investment. Additionally, some lecturers may resist adopting new technologies due to comfort with traditional methods, and there is a shortage of qualified trainers to deliver MR-specific instruction.

vii. Usability Problem of Technology

Mixed Reality (MR) technologies, including AR and VR, are still developing and often face usability challenges. Technical issues, complex interfaces, and lack of clear guidance can make them difficult for students and instructors to use effectively. Ensuring MR systems are user-friendly and accessible is essential for their successful integration in education (Ogunseiju et al., 2021) (Zhang et al., 2024).

viii. Problem of Technology with Conventional Education Method

Mixed Reality (MR) offers significant educational benefits by enhancing understanding and supporting active, student-centered learning. However, its integration faces challenges due to the dominance of traditional, teacher-centered methods, which emphasize passive knowledge delivery. This creates a gap between conventional practices and the exploratory learning MR promotes. Additionally, without explicit inclusion in the educational syllabus, instructors may resist adopting MR. Bridging this gap requires adjustments in curriculum design and teaching strategies (Abouelkhier et al., 2024) (Tayeh et al., 2021).

ix. Inflexibility of Education Content

Designing Mixed Reality (MR) content is more complex than creating traditional presentations, requiring specialized skills and the involvement of experts. Effective communication between lecturers and specialists is essential to align content design. However, modifying MR content can be time-consuming, as lecturers often depend on specialists. MR demands flexible, interactive content, making its development more resource-intensive compared to static teaching materials (Zhang et al., 2024; (Pellas et al., 2020).

x. Lack of Professional Designer and Skilled Specialist

Designing effective Mixed Reality (MR) content requires specialized expertise, yet there is a shortage of skilled designers and professionals in this field. While various MR hardware exists, the lack of qualified specialists limits the development and implementation of quality MR learning experiences (Ogunseiju et al., 2021) (Ke et al., 2016).

xi. Integration with Online Learning

MR enhances online learning through immersive, interactive experiences, but its integration requires careful planning to ensure compatibility and effectiveness in virtual classrooms (Tayeh et al., 2021).

III. RESEARCH METHOD

The approach that is going to be used in this study is the quantitative method which involves the questionnaire survey form as the medium of data collection. The respondents are both lecturers and students of construction related courses from public universities in Malaysia. Public universities are targeted due to their active role in advancing digital transformation initiatives aligned with national strategies like MyHE 4.0.

Research Objectives	Research Approaches	Respondents	Data Required	Data Analysis
RO1:	**Quantitative:** Questionnaire Survey	Lecturers and students of construction-related courses from public universities in Malaysia	Primary Data: **Potential** of Implementation of MR in Teaching and Learning of Construction-Related Courses	**Descriptive Method**: Frequency, Mean and Standard Deviation
RO2:	**Quantitative:** Questionnaire Survey	Lecturers and students of construction-related courses from public universities in Malaysia	Primary Data: **Challenges** of Implementation of MR in Teaching and Learning of Construction-Related Courses	**Descriptive Method**: Frequency, Mean and Standard Deviation

This study adopted the quantitative approach as it focuses on ranking the potentials and challenges of MR implementation in teaching and learning. Referring to the table above, the instrument for data collection is the questionnaire survey. The questionnaire survey will be distributed via an online platform including Email and WhatsApp. The survey is consists of 4 sections which are Background of Respondent, Basic Understanding of MR, Potential of Implementation of MR and Challenges of Implementation of MR. Based on the total population of 12,989 students and 1,233 lecturers, the sample size for the research would ideally be 370 students and 291 lecturers, according to the Krejcie and Morgan Table. This study employs purposive sampling to specifically target lecturers and students involved in construction-related courses at public universities, ensuring the relevance of responses to the research objectives.

A pilot test will be conducted at researcher's university with 10 participants (5 students and 5 lecturers) to evaluate the questionnaire's clarity and effectiveness. After completing the survey, brief interviews will be held to gather feedback. The reliability of the instrument was assessed using Cronbach's Alpha. The result yielded a Cronbach's Alpha of 0.943 for all 54 items, indicating excellent internal consistency. This suggests that the

questionnaire items are highly reliable and measure the intended constructions consistently. Since the value exceeds the commonly accepted threshold of 0.8, no major revisions were necessary before proceeding to the main data collection phase.

For this study, a descriptive analysis method will be used to evaluate questionnaire responses. This includes summarizing participants' characteristics and their understanding of Mixed Reality (MR) using frequency distributions, while the responses regarding the potential and challenges of implementing MR will be analyzed using measures of central tendency and dispersion, specifically the mean and standard deviation. The former data will be organized and managed using Microsoft Excel, while the latter data will be analyzed using SPSS. The results will be clearly presented through text, tables, and graphical representations.

The mean scores will be interpreted according to a 5-point Likert scale, where scores range from "Strongly Disagree" to "Strongly Agree." Visual aids such as charts, tables, and graphs will support the analysis, ensuring clear presentation of findings. The use of descriptive statistics helps to provide a comprehensive overview of both the potential and challenges of Mixed Reality (MR) implementation, offering a straightforward interpretation of the collected data.

IV. EXPECTED OUTCOME

The expected outcome of this research will help shape the understanding of Mixed Reality application in construction-related education. The potentials of MR implementation will be identified and categorized based on its functions and features in enhancing teaching and learning processes. Additionally, the challenges associated with MR adoption in construction education will be highlighted, focusing on areas such as technological limitations, lecturer readiness, and content flexibility. These findings will provide a comprehensive overview of MR's role in modernizing construction education and offer valuable insights to support future integration strategies.

CONCLUSIONS AND RECOMMENDATION

In conclusion, this research has identified the potentials and challenges of implementing Mixed Reality in the teaching and learning of construction-related courses. The analysis of MR's capabilities has provided valuable insights into its effectiveness in enhancing student engagement, improving design comprehension, and supporting interactive learning environments. However, several challenges such as high implementation costs, lack of technical expertise, and resistance to adopting new teaching methods have been highlighted, which may hinder the successful integration of MR in construction education.

Since this research focuses specifically on construction-related courses within selected institutions, it is recommended that future studies expand the scope to include a wider range of universities and disciplines to ensure more generalized and unbiased findings. Further research could also explore the perspectives of industry professionals to evaluate how MR can bridge the gap between academic learning and real-world construction practices. Additionally, it is suggested that future studies examine possible strategies to overcome identified challenges, including lecturer training programs, curriculum integration, and infrastructure development, to better support the adoption of MR technology in construction education.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the Quantity Surveying Department of UTM Johor and the supervisor for their support and funding.

ABBREVIATIONS AND ACRONYMS

MR	-	Mixed Reality
AR	-	Augmented Reality
VR	-	Virtual Reality

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EXPLORING THE STRATEGIES TO MITIGATE THE SHORTAGE OF BIM EXPERTS IN THE CONSTRUCTION INDUSTRY IN MALAYSIA

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ABSTRACT

Building Information Modelling (BIM) is rapidly acknowledged as a revolutionary tool in the construction sector, providing improved project coordination, efficiency, and sustainability. Nevertheless, its adoption in Malaysia is hindered by a significant shortage of BIM experts. The skills gap, caused by resistance to change, insufficient training, and high implementation costs, has slowed the industry's transition toward digital construction methods. This research seeks to explore the strategies to mitigate the shortage of BIM experts in the construction industry in Malaysia. The objectives are to (1) identify the factors contributing to BIM expert shortages in Malaysia's construction industry and (2) evaluate the impact of BIM expert shortages on the industry. A quantitative research approach is used, using structured surveys delivered to essential construction individuals, such as engineers, quantity surveyors (QS), contractors, and architects. A statistical analysis will be conducted to identify trends and relationships in the challenges associated with BIM adoption. The anticipated findings suggest that resistance to change, lack of proper training, and financial limitations are the primary obstacles, negatively impacting project performance and the industry's overall growth. This study offers insights into targeted interventions by advocating for standardized training programs, regulatory enhancements, and financial support measures to bridge the BIM knowledge gap, thereby accelerating the digital transformation of Malaysia's construction sector.

Keywords: Building Information Modelling (BIM), Resistance to change, BIM Experts, Quantitative Research, BIM Adoption

I. INTRODUCTION

BIM is a collaborative methodology that enables various construction professionals, including architects, engineers, contractors, and developers, to work together using a unified 3D model for project planning, design, and execution (Lorek, 2022). BIM is gaining recognition for its transformative impact on the construction industry, as it offers enhanced communication, coordination, and efficiency across all stages of a project. According to Doan et al. (2019), BIM's ability to improve schedule oversight, cost control, energy management, and facility administration has broadened its scope in building management. As noted by Yang et al. (2021), BIM's usage has become more prevalent, leading to significant improvements in project execution and a reduction in delays. Despite the growing application of BIM globally, the majority of research has primarily focused on its technical aspects, leaving managerial dimensions less explored (Oraee et al., 2017). Eadie et al. (2013) highlight that effective stakeholder involvement, driven by management, can enhance project performance, overcome organizational barriers, and foster collaboration between new graduates skilled in BIM and experienced professionals lacking such knowledge. Strengthening stakeholder interaction and management strategies, as suggested by He et al. (2017) is essential for addressing competency gaps and improving collaboration in BIM implementation. In Malaysia, despite the increasing significance of BIM, the construction industry faces a shortage of skilled BIM professionals. This deficiency in expertise hampers BIM's potential to improve project efficiency and reduces its overall effectiveness in construction. Therefore, this study aims to explore strategies to mitigate the shortage of BIM experts in Malaysia's construction sector, addressing a key gap in both academic and industry knowledge, and promoting the wider adoption and advancement of BIM in the region.

II. PROBLEM STATEMENT

The implementation of BIM in the construction industry faces several challenges, primarily stemming from a lack of technical expertise and reluctance to adopt new technologies. Research by Whyte & Bouchlaghem (2002) identifies technical problems such as system complexity and inadequate support as key barriers to BIM adoption. A significant issue contributing to the shortage of BIM professionals is the unwillingness of employees to acquire new knowledge, as many are content with existing methods and resistant to change (Khemlani, 2005). Additionally, organizational challenges, including concerns about the costs and potential disruptions caused by BIM adoption, further hinder its widespread use (Love et al., 2001). The high initial costs of BIM technology, including software acquisition and training, also deter companies from implementing BIM, fearing it may disrupt operations and hurt financial stability (Jamal et al., 2019). Moreover, the lack of interest from the younger generation exacerbates the shortage of BIM professionals in the construction sector. Studies by Sabongi and Arch (2009) and Chen & Gehrig (2011) suggest that many students are not motivated to engage with BIM, often finding it more challenging to learn than other technologies like CAD. Additionally, without a foundational understanding of building systems and construction procedures, students struggle to adopt BIM effectively (Ghosh et al., 2013). These issues, compounded by local economic, cultural, and regulatory challenges, prevent the full adoption of BIM in Malaysia's construction industry. This research aims to address these barriers by providing insights to bridge the BIM skills gap, improve industry knowledge, and promote sustainable practices.

III. LITERATURE REVIEW

3.1 Introduction to BIM Experts

The increasing complexity of construction projects has led to a rising demand for specialized BIM roles, such as BIM Managers, BIM Modellers, and BIM Analysts, each requiring distinct expertise in BIM technology, standards, and modelling (Barison & Santos, 2009). BIM Managers oversee project functions, enhance communication, and streamline processes (Howard & Björk, 2008), while BIM Modellers create detailed models and 2D documentation for various project stages (US GSA, 2009). BIM Analysts conduct simulations to evaluate building performance, guiding design choices, especially in MEP design firms (Applied Software, 2009). The success of BIM operations relies heavily on the use of 3D modelling software and Common Data Environments (NBS, 2019), with Autodesk Revit being the most widely used tool (52%) due to its model development and coordination capabilities, followed by Autodesk Navisworks (28%) for project review and collaboration (Shah, 2020; Bhattacharjee, 2024).

3.2 Current Issues of the BIM Experts shortages in the Malaysia's Construction Industry

The shortage of BIM expertise in Malaysia's construction sector significantly affects project efficiency, leading to delays and increased costs. A study by Othaman et al. (2021) reveals low BIM adoption, with only 8.2% of public sector professionals and 4.9% of private sector professionals using the technology. The lack of expertise hampers essential processes like design collaboration and dispute resolution, which disrupt schedules and budgets. BIM, with its AI-driven generative design and advanced features, provides better data quality and project outcomes than traditional CAD, yet the scarcity of skilled professionals limits its benefits (Storrier, 2021). Resistance to change is another issue, with the industry hesitating to adopt new technologies due to concerns about costs, disruptions, and the learning curve (Oesterreich & Teuteberg, 2019). Hartmann & Fischer (2009) argue that opposition to ICT in construction should be strategically managed to ensure smoother integration. Financial limitations also impede BIM adoption, especially for SMEs. Although investment in BIM rose from 33% to 54% between 2016 and 2019, it decreased to 44% by 2021, reflecting financial constraints. BIM software, such as Revit and Tekla, is significantly more expensive than traditional design tools, making it difficult for SMEs to afford (Latiffi et al., 2015). Furthermore, the lack of BIM training in Malaysian education and professional programs has contributed to the shortage of skilled professionals. Research by Mohamad & Khalid (2020) shows that BIM adoption is heavily influenced by perceived utility and user-friendliness, and Rahimee and Noh (2022) emphasize the need for better integration of BIM into university courses. Their study at UTHM highlighted that 84% of participants had inadequate exposure to BIM technology, stressing the need for improved education in the field.

3.3 Factors Contributing to the Shortage of BIM Experts in Malaysia's Construction Industry

The shortage of BIM experts in Malaysia’s construction industry can be attributed to several factors. One significant issue is the lack of standardized BIM guidelines, which leads to inconsistent training and a shortage of

skilled professionals (Hanafi et al., 2016). The absence of skilled trainers is another major barrier, as many organizations face difficulties using BIM due to the lack of qualified educators (Giligan & Kunz, 2007). The slow adoption of new technology also contributes, with industry professionals resisting the use of BIM due to cost concerns and the steep learning curve (Zainon et al., 2018). Furthermore, the lack of support from top management exacerbates the problem, with insufficient leadership commitment hindering the deployment of BIM technologies (Liu et al., 2010). Another contributing factor is the high cost of training, software, and hardware, which prevents companies from investing in BIM (Latiffi, 2015). Additionally, many professionals are unaware of BIM's capabilities, resulting in reluctance to embrace the technology (Al-Ashmori et al., 2020). Legislative issues, such as the lack of specific policies, also hinder BIM adoption, leaving firms without clear implementation strategies (Zhing & Ern, 2021). The global demand for BIM professionals further exacerbates the shortage, with many experts opting for opportunities abroad (CIDB BIM Malaysia, 2021). The lack of coordination in BIM-based designs, caused by insufficient expertise, also limits its effective use and increases the demand for skilled professionals (Volk et al., 2014). Lastly, technical constraints, such as reliance on automated systems and cloud-based storage, create additional barriers to BIM adoption (Mahamadu et al., 2020), further intensifying the shortage of qualified experts in the field.

3.4 Impacts of BIM expert shortages in the Malaysia's Construction Industry.

The shortage of BIM expertise in Malaysia's construction industry results in several negative impacts. The lack of skilled BIM professionals reduces collaboration among project stakeholders, as the potential of BIM to improve project coordination through cohesive 3D models and real-time data cannot be fully realized (Hosen, 2024). This leads to weaker project coordination and poor teamwork. Additionally, the shortage significantly increases project costs, as organizations are unable to adopt BIM effectively, missing out on the expected cost-saving benefits and efficiency improvements (Jin et al., 2014). The lack of expertise also affects operational efficiency, as limited automation and increased design errors hinder project performance (Chowdhury, 2024). Moreover, the absence of BIM professionals poses a substantial obstacle to sustainability, as BIM is critical for energy optimization and environmental impact assessments (Saxon, 2013). This shortage results in reduced market competitiveness, especially for smaller organizations, which struggle to compete for high-value projects without BIM expertise (BimCollab, 2024). The risk of errors and rework increases due to mistakes caused by design faults, modifications, and vendor oversights (Farouk et al., 2023). Project delays also become more prevalent, as the lack of BIM experts leads to poor project management and coordination, extending project timelines (Kosasih, 2024). Poor quality control is another result of insufficient BIM expertise, leading to costly errors and compromised project outcomes (Thaarrini, 2024). Furthermore, ineffective resource management emerges, as companies fail to effectively coordinate labor, materials, and schedules without BIM expertise (Verma, 2023). Finally, the shortage of BIM professional's stifles innovation and the adoption of emerging technologies such as AI, virtual reality, and machine learning, which limits the ability of organizations to improve project visualization, risk assessment, and data analysis (Ariono et al., 2022).

3.5 Strategies to Mitigate the BIM Expert Shortages in the Malaysia's Construction Industry

To mitigate the shortage of BIM experts in Malaysia's construction industry, several strategies have been proposed. One critical approach is the standardization of BIM processes, which would ensure uniformity across the industry, minimizing training inconsistencies and improving the overall quality of BIM competencies (Rahim et al., 2022). Another key strategy is enhancing the availability of skilled BIM trainers, which includes investing in qualified educators and offering training to school leavers to meet industry demands (CIDB, 2021). Leadership support and change management are also essential, as they can help shift traditional mindsets and foster a culture of innovation and continuous improvement in BIM adoption (Young, 2009; Ali et al., 2023). Additionally, securing top management support is necessary to ensure the successful integration of BIM into organizational strategies (Arif and Hasmori, 2022), while providing financial aid, including grants and incentives, can alleviate the financial burden of BIM adoption and training (CIDB, 2016). Further efforts should include developing programs to increase BIM awareness and understanding through seminars, workshops, and publications, addressing misconceptions about BIM (CIDB, 2019). Implementing legislative support is also crucial for creating standardized protocols and ensuring compliance with BIM practices, especially for large public projects (Fakiah et al., 2021). To lower the global demand for BIM experts, improving local career opportunities and offering competitive compensation packages is key to retaining talent (Thirosha, 2024). Strengthening BIM coordination training and standards will address coordination challenges and improve collaboration among stakeholders (Abu Bakar et al., 2021). Finally, investing in advanced BIM software and network infrastructure is vital for overcoming technical constraints and supporting large-scale projects, ensuring the efficient implementation of BIM technologies (Rizqy et al., 2021).

IV RESEARCH METHODOLOGY

Research Strategy

This research adopts a quantitative approach to investigate the shortage of BIM expertise in Malaysia's construction industry. By collecting and analysing numerical data, the study aims to identify trends, assess correlations, and generalize findings to a broader population, while also addressing key challenges associated with BIM implementation. Cross-sectional surveys are selected for their ability to capture a snapshot of current issues within the project timeline, providing timely insights for policymakers to address the BIM skills gap. The target respondents are professionals from various sectors of Malaysia's construction industry, including M&E engineers, quantity surveyors, contractors, structural engineers, and architects. These individuals are directly involved in BIM processes and are familiar with challenges such as inadequate training and a shortage of skilled personnel. The study focuses on the Malaysian region, where many significant development projects are ongoing. To ensure accurate and representative data, 143 questionnaires will be distributed via email to construction professionals across the country. A pilot test involving 10 respondents was conducted to ensure clarity and content relevance. Cronbach's Alpha was also used to assess the reliability of the instrument. Data analysis will include descriptive statistics and mean ranking to evaluate and prioritize key issues. This approach aims to capture diverse perspectives and identify both barriers to BIM adoption and potential solutions.

CONCLUSION

In conclusion, this study successfully addressed the shortage of BIM experts in Malaysia's construction industry by identifying key factors, assessing their impacts, and proposing effective strategies for mitigation. Future study also needs to prioritise the augmentation of data collecting and the incorporation of qualitative methodologies for enhanced comprehension. As a result, this report provides practical suggestions to improve BIM adoption and skill development in Malaysia's construction industry.

ACKNOWLEDGMENT

The author would like to express his gratitude to Energy, Geoscience, Infrastructure and Society Department of Heriot Watt University, Malaysia, especially the supervisor for funding this publication. The main author would like to express grateful appreciation to the research supervisor, Dr Azreen Ariff Bin Zulkeflee for his invaluable guidance and advice

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THE APPLICATION OF PRIVATE NETWORK CLOUD-BASED SYSTEM FOR MANAGING PROJECT DOCUMENTATION AND INFORMATION

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ABSTRACT

The anticipated complexity of project documentation and information is comparable to the growing complexity of construction projects and the ongoing expansion of construction companies. While paper-based management often leads to misplaced documents, bigger storage areas, and security vulnerability, cloud-based systems have emerged as an innovative solution to enhance effectiveness in data and information management. Construction firms are shifting to adopt private cloud-based systems to improve the management of documents and information within their firm and projects. This conceptual paper focuses on examining the role of private cloud-based management platforms in enhancing project document management within the construction industry. As construction projects generate vast amounts of documentation, efficient management is crucial for ensuring streamlined communication, security, and accessibility. Through literature review, it was discovered that private cloud-based systems enhance access to project information, improve document security, streamline collaboration, provide better version control, and enable reliable data backup and disaster recovery. These features ensure project teams work with updated documents, reducing errors and minimizing delays. However, several challenges hinder the adoption of private cloud-based systems. High initial costs, complex documentation processes, technical constraints, and the need for specialized training create significant barriers. Construction firms face difficulties transitioning from traditional methods due to financial burdens and the challenge of integrating extensive project documentation into cloud platforms. To further this research, this paper proposes conducting qualitative research via semi-structured interviews with a construction firm that has implemented and adapted a private cloud-based system. The study aims to gain insights into the practical challenges and benefits of these systems, contributing to strategies for optimizing cloud-based document management in construction projects.

Keywords: Private cloud-based system; Information management; Project documentation; Construction firm

I. INTRODUCTION

The construction industry is a key driver of economic growth. As the industry grows, so does the complexity of managing project documentation and information. Inefficient document management often leads to project delays, cost overruns, and legal disputes (Hashemi et al., 2020). Traditionally, construction documentation relied on paper-based archives, which were susceptible to loss, damage, and inefficiencies (Dubes, 2024). The digital transformation of document management, through Document Imaging Processing (DIP) systems and later Electronic Document Management Systems (EDMS), has significantly improved accessibility and security (Wang & Plume, 2012). More recently, cloud-based systems have become integral in managing construction documents efficiently, particularly private network cloud-based systems, which provide secure, real-time access to critical project information (Chen & Ying, 2022).

Despite their advantages, private network cloud-based systems come with challenges such as high initial costs, complex infrastructure, technical expertise requirements, and resistance to change among construction professionals (Abdullahi et al., 2023). However, when effectively implemented, these systems enhance productivity, collaboration, and decision-making in construction project management (Almaatouk et al., 2020). This research aims to investigate the application of private network cloud-based systems for managing project

documentation and information. This study has three key objectives: to analyse the application of private network cloud-based system for project documentation and information in construction firm, to determine the effectiveness of private network cloud-based systems in managing project documentation and information, and to identify the challenges of private network cloud-based systems in managing project documentation and information from the perspective of a contractor firms, providing insights into its role in improving project documentation and information management.

II. LITERATURE REVIEW

PROJECT DOCUMENTATION AND INFORMATION

2.1.1 The Role of Construction Firms in Handling Project Documentation and Information

Construction firms are relied upon to be extremely liable for administering project data. They need to be confident that all records are complete, truthful, and available at every stage of the project. This ranges from construction documents, including contracts and designs, to post-construction documents like manuals and construction as-built documents (Olubukola et al., 2024). In this way, through the formal maintenance of these records, firms provide accountability for certain activities and provide stakeholders with proper information.

Construction firms also perform the function of information transfer between the stakeholders so that the right information is given to the right recipient at the right time. This role becomes even more important in a large project with contractors, consultants, and regulatory bodies involved during and after the construction work. According to CIDB (2020), with the improvement in technology, firms are now incorporating the use of cloud technology for effective collaboration and to fight against data inconsistency. This essentially makes it important for modern construction firms to have well-managed project documentation and information systems.

2.1.2 Project Documents as Core in Project Documentation and Information

Project documents can be defined as the foundation of project documentation and information management systems (Autodesk, 2024). The documents help give a physical form to the ideas that otherwise remain informal, especially when it comes to decision-making or contract agreements. For instance, contracts give the legal structure within which a project will be implemented to detail every aspect of the agreements of the parties involved. However, project documents also require monitoring and control processes because documents represent a reference framework that enables one to verify if the process is right on the path or deviates from the set objectives. They also have an important use in managing risks by recording possible problems and how they can be solved (CIDB, 2020). In the conflicting issues, these documents act as a basis for intervening in a conflict and the fulfillment of a contract. It is important to maintain the adjectives in these documents as any mistake or omission can cause a lot of project failures (Olubukola et al., 2024).

2.1.3 Issues in Managing Project Documents

Controlling mega-project documents continues to pose a big challenge in construction projects. Whenever large-scale projects are undertaken, it is impossible to manage such huge volumes of documents manually. Traditional methods of managing project documents are plagued by inefficiencies. Physical storage methods make retrieval time-consuming and increase the risk of document loss due to mishandling, natural disasters, and how one controls access to the different areas in the building. If system controls are not implemented, anyone can access key documents that viably threaten the security of projects or their confidentiality (Autodesk, 2024). These difficulties are compounded by the increasing complexity of construction projects. Digitalization has improved document security, but standard cloud-based systems still pose risks such as data breaches and unauthorized access (Aslan et al., 2023).

2.1.4 Evolution of Technology for Managing Project Documents in Construction

The history of document management dates back to the late nineteenth century with the invention of the archive. This method remained the main way of storing documents in the construction world for most of the 20th century (Dubes, 2024). The development of information technology contributed to paper documentation beginning to take an electronic form. In 1980, primitive forms began to evolve into more modern systems with the appearance of Document Imaging Processing (DIP) systems (Dubes, 2024). These were the electronic versions of archive cabinets where documents were stored and indexed. Slightly more advanced systems made it possible to route documents within the organization (Dubes, 2024). The widespread use of the Internet and the development of computer networking have made possible the use of document management systems for project documentation and transfer. The maturity of CAD and other disciplinary-based software has made the production of Electronic

Documents System (EDMS) a daily practice for the construction industry ((Wang & Plume, 2012). Manual practices because of IT advancement have progressively evolved into electronic systems in a bid to enhance access, sharing, and exchange of information. Document sharing has become so important that the proliferation of internet access has driven several professional information technology companies to develop commercial web-based systems for document management in the construction industry, called cloud-based systems (Tung et al., 2021).

CLOUD-BASED SYSTEMS IN CONSTRUCTION PROJECTS

2.2.1. Differences Between Private and Public Cloud-Based Systems.

Although the public and private cloud storage providers provide the central location for storing data and real-time internal access, the difference is in ownership and security measures. Public cloud services are centrally controlled by third parties and are used by several organizations at the same time. Even though they are cost-effective, they have areas of concern as regards to data breach and compliance. However, private cloud systems were the implementation of the cloud systems on dedicated servers where firms have better control on data and security aspects. This makes them suitable to be used in construction projects that manage private data, including but not limited to financial records and architectural or engineering designs (Park et al., 2023).

THE EFFECTIVENESS OF PRIVATE CLOUD-BASED SYSTEMS IN MANAGING PROJECT DOCUMENTATION

2.3.1 Improved Access to Information

The advantage of using private cloud-based systems for project documentation and information management is that project data is more easily available. Manual paper-based systems, or local storage, can cause significant delays when trying to obtain up-to-date data. Web-based systems ensure that only authorized personnel are granted permits to access the project documents anytime they want by logging in from anywhere (CIDB, 2020). This liberal approach is very effective in large construction projects where people are spread out in areas and possibly in different zones or most probably performing their tasks online. Further, private cloud systems give added convenience in that all documents are stored ultimately in one pool as documents are no longer physically stored in file cabinets. Cloud storage is generated in a way that all the participants can refer to the most recent version of any document to avoid misunderstanding. Private cloud-based systems provide real-time access to project documents, reducing delays caused by manual paper-based systems (CIDB, 2020).

2.3.2 Enhanced Document Security

Private cloud-based systems have provided for high levels of protection of such data that belong to the project. These systems utilize encryption techniques to safeguard data both during transmission and while at rest (Olubukola et al., 2024).. Moreover, private cloud systems provide permissions over access in a particular business environment, with many people having no permission to access information that belongs to company members. Access rights can be set based on the roles of the user so that achieving and maintaining good control is easy since confidential details are safeguarded (CIDB, 2020). This level of control minimizes the likelihood of data leakage and violation of the regulation standards and acts like data protection and privacy (Aslan et al., 2023).

2.3.3 Streamlined Collaboration

Cloud-based document management fosters collaboration by enabling multiple stakeholders to work on the same documents simultaneously (Autodesk, 2024). These systems also have co-editing capabilities in the form of document writing, commenting, and task completion, where many people can work on the same document without erasing the work of the other person. The facility of commenting and tracking changes facilitates the way of working together between contractors, engineers, architects, and all project stakeholders. First, it means that decision-making is becoming more efficient, and issues can be easily spotted and solved in contrast with construction projects where efficiency and seamless cooperation between different teams is very helpful (Park et al., 2023).

2.3.2 Better Version Control

Version control is a crucial advantage of private cloud-based systems, as outdated or conflicting information often leads to costly errors in construction projects (Autodesk, 2024). Cloud systems maintain detailed version histories, allowing users to track changes and revert to previous versions when necessary (Olubukola et al., 2024).

2.3.3 Enhanced Data Backup and Disaster Recovery

Private cloud-based systems provide automated data backups, ensuring that project information remains intact even in the event of hardware failures or cyber-attacks. Unlike traditional document management methods, which are vulnerable to data loss, cloud systems ensure continuity through secure storage and recovery solutions (Autodesk, 2024).

CHALLENGES IN MANAGING THE PRIVATE NETWORK CLOUD-BASED SYSTEM

2.4.1 High Initial Costs

The deployment of private cloud-based systems requires significant investment in infrastructure, software, and cybersecurity measures. This ranges from the cost of equipment, both computer hardware and software, and the costs of developing the physical and digital infrastructure that comprises dedicated servers, high-speed internet, and high-level cybersecurity (Autodesk, 2024). Additionally, private clouds need strenuous updates and maintenance to keep them effective and economically secure. This entails either hiring new staff with IT specializations or outsourcing the services, which fixes more costs. Unlike public cloud solutions that operate on a subscription basis, private cloud implementation involves high upfront capital expenditure (Park et al., 2023). The Klang Valley Mass Rapid Transit (MRT) project under Gamuda-MMC joint venture represents a major private cloud infrastructure capital expenditure. The consortium behind the Klang Valley Mass Rapid Transit project spent substantial resources to establish information management platforms which managed complex data and coordination requirements (AECOM, 2015).

2.4.2 Complex Documentation

The construction business is unique in that it is so complicated that it comprises many participants, intricate plans and designs, and many legal papers. Converting these documents to a private cloud system may be quite challenging. Many physical documents have to be scanned for digitization, and contracts have to be reformatted for harmonization, which by itself costs a considerable amount of time (Autodesk, 2024). Furthermore, dealing with a number of versions and the organization of the document structure in the cloud system in large-scale projects might be difficult (Park et al., 2023). Main contractors from Johor Bahru had basic knowledge of cloud computing yet refused actual implementation because documentation procedures were difficult to understand. The conversion process of physical documents to digital format involves extensive work that includes document scanning as well as file reorganization and formatting for new digital systems and this task becomes harder when dealing with extensive projects (Kai et al., 2019).

2.4.3 Technical Constraints

The construction industry can, at times, experience challenges with access to proper IT resources. These can be a result of the location of a project, especially within rural areas. Emote areas lack reliable electricity and proper internet connection (Bello et al., 2020). The need for infrastructure can therefore not be overemphasized because, without it, efficiency and access to cloud-based systems are virtually impossible. Irrational constraints impede the availability of internet and power for rural Malaysian construction sites to the extent that implementing the cloud becomes ineffective or completely blocked at times. The strengths of infrastructure determine how much advantage organizations can gain from real-time cloud system usage (Chween et al., 2018).

2.4.4 Educational Programmes and Professional Training

These systems contain additional features which make their usage more efficient; however, their efficiency depends on the user. It is common for many construction firms to fail in the attempt to close this knowledge divide especially because the existing workforce may not have interacted with computer software or cloud programs in the recent past (Autodesk, 2024). Lack of understanding and acceptance of change may stem from the maturity of the professionals as they may find the new means of doing more work unessential or too complicated, especially having to change from traditional ways to the use of new technologies (Park et al., 2023).

2.4.5 Lack of Commitment from Stakeholders

Unfortunately, the successful deployment of private cloud-based systems can only be done through the collaboration of project managers, contractors, clients, and information technology professionals. Nevertheless, resistance to change and unaligned goals and objectives sometimes defeat the intended efforts (Onatere-Ubrurhe et al., 2024). If the concepts remain abstract and not tightly connected to an organizational purpose, the application of private cloud systems is very likely to encounter numerous challenges and create various losses in terms of

effectiveness and resources. Research into Malaysian construction firms disclosed several digital system failures due to inadequate executive backing together with employee opposition to change (Aziz & Salleh, 2014). Research by Onatere-Ubrurhe at al. (2024) indicates implementation failure of cloud systems occurs when deployment lacks specific advantages or deployment rationale.

III. METHODOLOGY

Research Process

According to Figure 1.0, the flow of the research process starts with the problems identification. It is being identified by searching the data based on issues related to managing project information, collaboration, and compliance in Malaysia's construction. It can be found in industry conferences, CIDB Malaysia publishes guidelines and reports on digitalization in the construction industry, and journals. It proceeds to the formulation of research objectives: to analyse the application of private network cloud-based system for project documentation and information in construction firm, to determine the effectiveness of private network cloud-based systems in managing project documentation and information, and to identify the challenges of private network cloud-based systems in managing project documentation and information will be identified. These objectives will be the guideline for this research, which be the aim that need to achieve.



Figure 1.0 Process of Research Methodology

RESEARCH METHOD: QUALITATIVE APPROACH

This study employs a qualitative research design and follows a structured research process. It begins with identifying the research problem, focusing on the issues of project documentation and information in construction. A comprehensive literature review is conducted to establish a foundational understanding of the topic and develop a conceptual framework. with a minimum of three experts, including quantity surveyors, project managers, and contract executives from a contractor firm. These professionals are selected based on specific criteria. They must be currently utilizing private cloud-based systems for project documentation and information management to evaluate their perception on the application of private network cloud-based system for project documentation and information in construction firm, the effectiveness and challenges of private network cloud-based systems in managing project documentation and information. Then, data collected will be analysed using thematic analysis to identify the applications, effectiveness, and challenges. Finally, findings will be synthesized to develop a structured framework. The research uses thematic analysis for data analysis because this technique provides flexibility when studying complex experiences that stem from direct participant involvement. Thematic analysis use to identify patterns within qualitative data through systematic analysis so they can gain rich insights into participant experiences. Given that this study involves interviews with industry professionals—quantity surveyors, project managers, and contract executives—who actively engage with cloud-based platforms, thematic analysis will effectively capture their nuanced perspectives, practices, and challenges related to the system's implementation and performance. The structured qualitative research design along with purposive and snowball sampling methods receives support from thematic analysis. It allows for the integration of diverse viewpoints from various experts while maintaining coherence across the dataset. The research method enables users to combine analytical findings between interview-based insights and literature review information to strengthen overall validity and depth.

TARGET POPULATION AND SAMPLING

The target population for this study refers to the professionals who are directly involved in the use of cloud-based management platforms in one contractor firm. These professionals will provide real-world insights into the effectiveness of cloud-based management platforms for project document management, making them ideal candidates for this study. Due to the nature of the topic in question, the importance of using purposive sampling comes in handy. Information from the first participants is used to recruit the next ones, and diverse expertise and views are incorporated (Naderifar et al., 2017). Therefore, this research will adopt the thematic analysis as it is seen to be the most suitable and the best method to be utilized in this research, as both data from interviews and literature review are being conducted in this study. Thematic analysis complements the snowball sampling method by allowing researchers to explore the experience and perspectives of participants who have been using cloud based system.

CONCLUSION

This study emphasizes the application of private network cloud-based systems for project documentation and information in construction firm. By examining contractor perspectives, this study highlights the effectiveness and challenges of private network cloud-based systems in managing project documentation and information. While this paper serves as a foundational study, further research will be conducted to validate and refine the research. By continuously improving these technologies and addressing potential challenges, the construction industry can fully leverage cloud-based solutions to optimize document management and enhance project outcomes.

ACKNOWLEDGMENT

The authors would like to express sincere thanks to the School of Housing, Building and Planning (HBP) for funding this publication.Pulau Pinang, Malaysia.

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REVOLUTIONIZING CONSTRUCTION PRACTICES: A STUDY OF BIM TECHNOLOGY UPTAKE AMONG QUANTITY SURVEYORS IN KLANG VALLEY

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ABSTRACT

BIM implementation has experienced significant growth in recent years among Quantity Surveyors in Malaysia. BIM technology offers the potential to transform the construction development processes for a higher quality outcome in the construction sector. However, there is still lacking in the implementation of BIM resulting complex structure of construction work leads difficulties in project coordination. This research is to examine the implementation of BIM technology by Quantity Surveyors in the Klang Valley, Malaysia. The main aim of the research is to identify criteria, discuss advantages and investigate problems related to BIM implementation among Quantity Surveyors in Klang Valley via a quantitative method to explore the stakeholder viewpoints on their insights. The expected results aim to guide efforts to enhance efficiency and cooperation in the construction sector.

Keywords: (Building Information Modelling, Quantity Surveyors, Criteria, Benefits, Challenges)

I. INTRODUCTION

The construction sector plays a pivotal role in Malaysia's economic development, as highlighted by data from Bank Negara Malaysia and Khan et al. (2014). It not only contributes significantly to the nation's Gross Domestic Product (GDP) but also supports improved living standards and infrastructure development. As a developing country, Malaysia recognises the strategic importance of construction in driving both economic progress and societal well-being.

Globally, Building Information Modelling (BIM) has emerged as a transformative force in the construction industry. In the United Kingdom, for instance, BIM adoption rose from just 13% in 2011 to over 73% by 2020, according to the National Building Specification (NBS) report and Wang and Chen (2023). This rapid growth reflects a shift in BIM's role—from being a mere technological tool to becoming a comprehensive strategic management approach. The UK demonstrated its commitment to digital transformation by mandating the use of BIM Level 2 for all public projects by April 2016.

However, the successful implementation of BIM is not solely reliant on technological advancements. Scholars emphasize the importance of integrating business process models, adopting digital workflows, and promoting effective information exchange in order to fully realise BIM's potential. Chen et al. (2022) note that BIM was initially developed to streamline labour-intensive tasks and validate project workflows, but its capabilities have since expanded to include decision-making support and construction process simulation. This evolution has significantly altered how construction projects are managed.

Today, BIM is a vital tool for planning, development, and management across the entire construction project

lifecycle. It enables seamless collaboration, efficient data sharing, and integrated management, replacing traditional fragmented processes. This transition towards a more systematic and technology-driven approach is key to enhancing productivity, efficiency, and overall performance in the global construction industry.

II. PROBLEM STATEMENT

Construction projects are inherently complex, involving multiple phases and stakeholders from the initial planning stage to project completion. This complexity generates extensive documentation and data, which must be carefully managed throughout the project lifecycle. Effective collaboration and integration among various professionals—often from different organisations—are essential to achieving project goals. However, the reality of fragmented information and excessive paperwork frequently leads to misunderstandings, duplication of efforts, and conflicts among stakeholders. These issues can severely disrupt communication, reduce productivity, and compromise overall project efficiency (Al-Ashmori et al., 2020).

Globally, the construction sector has long been plagued by persistent challenges, including low productivity, delays, and frequent budget overruns. These ongoing difficulties not only hinder project success but also strain industry growth and development (Raza et al., 2023). Traditional construction practices often fall short in addressing the increasing complexity of modern projects, especially under constraints such as limited financial resources and rising client expectations. As a result, the industry is in urgent need of innovative solutions that can streamline workflows, improve coordination, and enhance overall performance.

III. RESEARCH AIM AND OBJECTIVES

This research aims to thoroughly evaluate the implementation of Building Information Modelling (BIM) technology uptake among Quantity Surveyors in Klang Valley. The objectives of this research is to identify the criteria for using BIM technology, determine its benefits, and explore the obstacles connected with its implementation by Quantity Surveyors.

IV. LITERATURE REVIEW

The adoption of Building Information Modelling (BIM) technology has grown significantly within Malaysia's construction industry, largely due to its numerous advantages. BIM not only enhances project efficiency but also plays a crucial role in evaluating and supporting environmentally sustainable construction practices. It is widely recognised for its effectiveness in promoting green building initiatives, minimising construction risks, managing project complexity, and resolving conflicts during project execution (He et al., 2017). Since 2007, Malaysia's construction sector has taken proactive steps to improve overall building performance through the integration of BIM. This section will provide a more detailed explanation of Building Information Modelling (BIM), specify the criteria for adopting BIM technology among Quantity Surveyors in Klang Valley, highlight the advantages of using BIM technology, and examine the difficulties connected with its implementation uptake among quantity surveyors.

CRITERIA OF BIM TECHNOLOGY

The adoption of Building Information Modelling (BIM) technology among Quantity Surveyors in Klang Valley is shaped by several important criteria. One of the most significant is training and skill development, as many QS professionals still lack the technical expertise required to operate BIM tools effectively (Anwar et al., 2024; Roslan et al., 2019). Without adequate training, BIM cannot be used to its full potential in cost estimation, planning, and project coordination. Cost and budget constraints are also a major concern, as firms must invest heavily in software, infrastructure, and ongoing staff development to support BIM implementation.

In addition, technology infrastructure plays a critical role. BIM relies on high-performance systems and cloud-based platforms to manage complex data, and poor infrastructure can severely limit its effectiveness (Tran et al., 2023). Regulatory and government requirements further influence adoption, with industry standards and policy support encouraging firms to comply and modernise their processes. Another key factor is the return on investment (ROI), where organisations assess long-term benefits such as reduced delays and better cost control before committing to BIM (Manzoor et al., 2021).

Market trends and project complexity also contribute to the decision-making process (Ola-Ade et al., 2023). As construction projects become more advanced, BIM is increasingly viewed as essential for managing intricate designs and large-scale developments. The availability of success stories and case studies provides practical evidence of BIM's advantages, giving firms the confidence to adopt it. Lastly, collaboration and integration remain

vital. BIM supports a unified digital environment where Quantity Surveyors, architects, engineers, and contractors can work together efficiently, leading to improved outcomes and stronger project alignment. In summary, the successful implementation of BIM requires a combination of skilled professionals, financial investment, technological readiness, regulatory support, and strong interdisciplinary collaboration. Addressing these factors is crucial to ensuring long-term efficiency and competitiveness in the Malaysian construction industry.

BENEFITS OF BIM TECHNOLOGY

The adoption of Building Information Modeling (BIM) among Quantity Surveyors in Klang Valley brings a range of significant benefits. Cost savings remain the most commonly highlighted advantage, as BIM supports better budget allocation, reduces material waste, and improves financial planning (Kineber et al., 2023; Chan et al., 2020; Zainon et al., 2016). Time savings are also frequently noted, with BIM streamlining workflows, automating tasks, and helping to minimize project delays—ultimately boosting overall efficiency.

Improved collaboration is another key benefit, as BIM enhances communication and coordination among stakeholders, promoting greater project integration (Ismail et al., 2019; Babatunde et al., 2020). Accurate cost estimation is also made possible through precise quantity take-offs and cost forecasting, enabling more informed financial decisions. BIM further contributes to increased productivity by minimizing errors, reducing repetitive tasks, and improving project workflows (Kamal Mihad, 2020).

In addition to these core advantages, BIM supports risk reduction by enabling early identification and mitigation of potential issues. Mustapa and Jamaluddin (2022) mentioned that Real-time updates provide instant access to the latest project data, enhancing adaptability and decision-making. Although mentioned less frequently, the shift toward paperless construction and sustainability reflects the industry's growing focus on digital efficiency and environmentally responsible practices (Ying et al., 2022; Kineber et al., 2023). Overall, these benefits demonstrate BIM's vital role in improving the performance, accuracy, and sustainability of construction projects managed by Quantity Surveyors.

CHALLENGES OF BIM TECHNOLOGY

The adoption of Building Information Modeling (BIM) among Quantity Surveyors in Klang Valley presents several challenges that require strategic attention. According to Kamal Mihad (2020), One major issue is software incompatibility, which hinders data exchange across different platforms, highlighting the need for standardized systems. Similarly, the lack of standard rules creates regulatory inconsistencies that limit uniform adoption. Resistance to change is another critical barrier, with many professionals reluctant to shift from traditional methods to digital workflows, pointing to the need for change management and training (Zainon et al., 2018).

Financial and time constraints also pose challenges, as firms must invest in software, training, and system integration—raising concerns about affordability and return on investment. A shortage of BIM expertise further reflects the industry's skills gap, emphasizing the importance of integrating BIM training into education and professional development. Legal uncertainties, including data ownership and liability, call for clearer contractual frameworks. Issues with communication and collaboration also persist, particularly when managing multidisciplinary teams, requiring better project coordination tools and stakeholder engagement.

Other barriers include a lack of documented case studies, limited government support, and insufficient legal backing, all of which reduce confidence in BIM adoption (Wong and Gray, 2019). Overall, these challenges reveal that a successful transition to BIM requires a comprehensive strategy that includes regulatory standardization, workforce training, financial support, and stronger collaboration across the industry. By addressing these issues, Quantity Surveyors in Klang Valley can move toward a more digital, efficient, and sustainable construction environment.

V. RESEARCH SCOPE

This study investigates the adoption of Building Information Modeling (BIM) among Quantity Surveyors in Klang Valley, aiming to enhance understanding, highlight its benefits, and identify key implementation challenges. It promotes technical innovation by showcasing BIM's impact on efficiency and cost-effectiveness, while offering practical insights into the barriers faced during adoption. Klang Valley was chosen as the research area due to its status as a major economic hub with a high concentration of construction activities (Chong, B. L.,

et. al, 2020). This makes it an ideal and representative location for examining BIM adoption within the Malaysian construction industry.

VI. RESEARCH METHODOLOGY

This study adopts a quantitative research methodology, which is well-suited for collecting and analyzing data from a large population, allowing for systematic comparisons and the quantification of relationships between variables (Apuke, 2017). This approach enables generalization of findings, supports accurate measurement, and provides reliable statistical analysis, making it ideal for exploring BIM adoption among Quantity Surveyors. The process involves the development of structured research questions, the design of tailored survey instruments, and careful sample selection. Despite its strengths, such as objectivity and replicability, the method also faces challenges related to data quality, resource demands, and assumptions of linearity. To address these issues, strategies like pilot testing, reliability analysis, and advanced statistical tools are employed to ensure valid, reliable, and cost-effective research outcomes (Musa Peter, 2017).

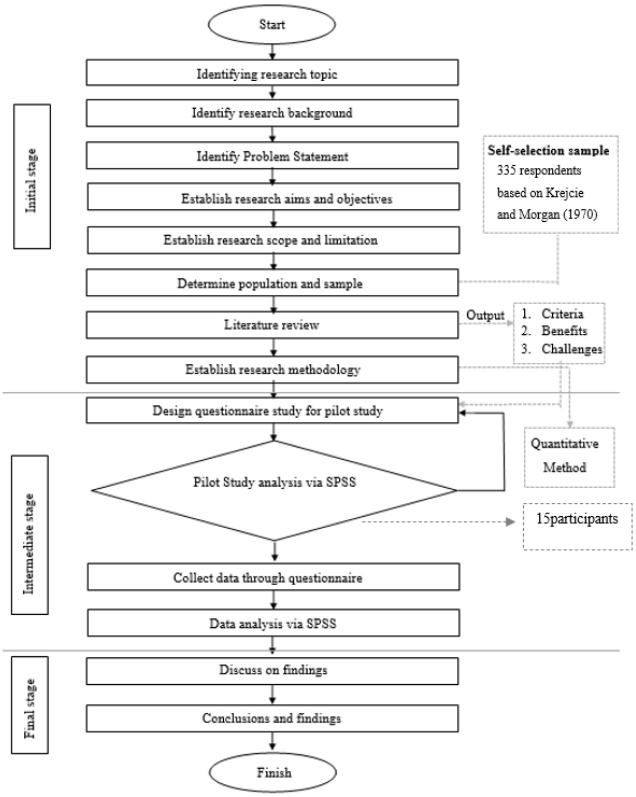


Figure 1.0 Flowchart of research process

Initial Stage

The initial phase of the research process lays the groundwork for the entire study. It begins with selecting a meaningful and focused topic, often inspired by personal interest or gaps in the field (Singh, 2021). A review of existing literature follows, helping to establish context and identify relevant theories. During this phase, the problem statement is clearly defined, along with the research aim and objectives to ensure clarity and focus. Researchers also set the scope and limitations, outlining the study's boundaries and acknowledging potential biases. Finally, the target population and sample are determined, forming the basis for data collection and ensuring the results are relevant and applicable. Together, these steps provide a clear framework and direction for the research.

Intermediate Stage

The intermediate phase of the research process focuses on the practical execution of the study plan. It begins with designing a structured questionnaire for a pilot study, ensuring clarity, validity, and reliability. The pilot test helps refine the instrument before the main data collection. SPSS software is then used to analyse the pilot data, assessing the quality of survey items and confirming the instrument's effectiveness. Following this, data is collected from the target sample in accordance with ethical guidelines. SPSS is again used for detailed data analysis, ensuring accuracy and consistency. This phase marks the transition from data collection to the generation of meaningful insights.

Final Stage

The final phase of the research process focuses on analysing findings, drawing conclusions, and making recommendations. Researchers begin by interpreting results in relation to the research objectives and existing literature, identifying whether the findings support or challenge prior knowledge (Binaymin, 2019). This is followed by formulating a conclusion that summarises key insights and proposing recommendations for future research, policy, or practice. The process concludes with the preparation of a well-structured research report, including proper formatting, citations, and proofreading. A systematic approach throughout this phase ensures the study's clarity, credibility, and contribution to the field.

POPULATION AND SAMPLING

This study focuses on the adoption of Building Information Modelling (BIM) among Quantity Surveyors in Klang Valley, Selangor, in response to ongoing issues in the construction industry such as delays, fragmentation, and inefficiencies. Despite government support, BIM adoption remains low. The research targets registered Quantity Surveyors under the Board of Quantity Surveyors Malaysia (BQSM), specifically within Klang Valley, where 2,482 QS professionals are based. Using Krejcie and Morgan's (1970) sample size table, a representative sample of 335 respondents was determined. A clearly defined research scope ensures focused data collection, accurate analysis, and relevant findings tailored to the local context, increasing the study's value to both academia and the construction industry.

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Figure 2.0 Sample Size (Source: Krejcie and Morgan, 1970)

RESEARCH ACTIVITIES

Descriptive analysis is a key method in research for summarising and interpreting data. It helps researchers understand the basic characteristics of a dataset before conducting more complex statistical tests. This approach uses measures such as mean, median, mode, range, variance, and standard deviation to reveal patterns and data distribution (Loeb, S., et. al, 2017). Graphical tools like histograms, frequency distributions, and box plots further aid in visualising trends and outliers. As an essential first step in the research process, descriptive analysis provides valuable insights that support informed decision-making and evidence-based practices.

SPSS SOFTWARE

The study will employ SPSS software as a tool. SPSS, short for Statistical Package for the Social Sciences, is extensively adopted by researchers and analysts for doing statistical analysis. The primary goals of this project involve the management of data, the analysis of statistics, and the visualisation of data (Rahman, 2021). Researchers utilise SPSS to effectively arrange, handle, and examine large datasets, applying various statistical approaches such as descriptive statistics, hypothesis testing, regression analysis, and multivariate analysis. One

significant benefit of SPSS is its user-friendly interface, which allows researchers to do intricate statistical analyses without needing advanced programming abilities. Moreover, SPSS provides powerful features for generating graphic representations of data, which aid in the understanding and presentation of study results. SPSS is the ideal programme for this survey because of its versatility and extensive statistical capabilities. It allows for full data analysis and the development of significant insights.

VII. EXPECTED OUTCOME

This research is expected to generate significant outcomes aligned with its primary objectives, namely to identify the criteria for BIM adoption, determine its benefits, and examine the challenges faced by Quantity Surveyors in Klang Valley. The study aims to contribute to a deeper understanding of the current level of BIM integration within quantity surveying practice, while revealing the key factors that influence its successful implementation. In addition to addressing these core aims, the research will explore methods to enhance awareness of BIM technology within the construction industry, recognising that awareness plays a vital role in promoting wider adoption. Strategies such as embedding BIM education into university curricula, offering structured training and technical support from software providers, and introducing government-led incentives or funding schemes are expected to be identified as potential enablers. Ultimately, the outcomes of this study will inform future strategies to advance digital transformation in the Malaysian construction sector by enhancing professional competency, improving project efficiency, and fostering interdisciplinary collaboration.

CONCLUSION

This study will examine the transformative potential of Building Information Modelling (BIM) for Quantity Surveyors in Malaysia's construction industry. It highlights the importance of increasing BIM awareness, showcasing its benefits such as improved efficiency, collaboration, and cost-effectiveness. While the study acknowledges various adoption challenges, it also offers strategic insights to help overcome them. Overall, the research emphasizes BIM's role in modernising QS practices, enhancing competitiveness, and contributing to the advancement of Malaysia's construction sector both locally and globally.

ACKNOWLEDGEMENT

I sincerely thank all who supported me in completing this dissertation. Special appreciation goes to my supervisor, Ts. Irna Nursyafina, for her guidance and support. I am also grateful to my family for their constant encouragement, and to all participants and interviewees whose input enriched this research. This achievement would not have been possible without your collective support.

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IMPLEMENTATION OF LIFE CYCLE COSTING (LCC) USING BUILDING INFORMATION MODELLING (BIM) AT DESIGN STAGE IN MALAYSIA

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ABSTRACT

The research analyses the implementation of Life Cycle Costing (LCC) within Building Information Modelling (BIM) for design stage in Malaysia's construction sector. The framework of Life Cycle Costing specifies cost evaluation of all project stages from procurement to operation and maintenance and disposal whereas Building Information Modelling boosts project efficiency through digital modelling practices which integrate project data. Industrial professionals show reluctance to adopt LCC integration into BIM because they have limited knowledge of these systems and inadequate training in their usage along with resistance to change. The study investigates the essential components that enable LCC application in BIM system while analysing implementation barriers as well as evaluating cost management advantages from integration. The research design involved a survey-based quantitative study of quantity surveyors working in government agencies and developers and consultants as well as contractors. In this research descriptive analysis proved essential for studying BIM-LCC methods together with identifying readiness levels within the industry and understanding barriers that prevent adoption. The study uncovered fundamental obstacles which mainly consisted of a shortage of BIM-specialized personnel together with inadequate software deployment alongside the discursive emphasis on short-term costs over total cost efficiency. Developed through this study were new approaches to boost BIM-LCC acceptance which help construction professionals better manage costs during planning and operation. The research works toward eliminating adoption barriers and enhancing industry knowledge that leads to making LCC a standard practice in BIM implementation.

Keywords: Life Cycle Costing, Building Information Modelling, Design Stage, Commercial Properties, Quantity Surveyor

I. INTRODUCTION

Digital technologies have brought substantial changes to how construction cost planning works today. The adoption of Life Cycle Costing (LCC) during recent years has become crucial for building sustainability and lifecycle financial choices. Building Information Modelling (BIM) stands as a fundamental digital technology which enables construction project representation along with simulations. The Malaysian construction industry has not effectively employed LCC and BIM integration at the design stage for cost management purposes although these methods operate independently.

The research explores current practices of LCC and BIM integration at the design level for commercial buildings in Malaysian real estate markets. The paper examines integration benefits and establishes requirements along with related documentation while analysing why professionals avoid using this approach. A quantitative survey method was used in this research to obtain applicable results which support sustainable cost-effective decisions at the beginning of projects while following CR4.0 framework.

The objectives of this study are:

i. To identify the use of Life Cycle Costing (LCC) in Building Information Modelling (BIM) at design stage focusing on commercial property.

ii. To determine necessary requirements and documents to establish Life Cycle Costing (LCC) in Building Information Modelling (BIM).

iii. To analyse the barriers and challenges in implementing Life Cycle Costing (LCC) adoption in Building Information Modelling (BIM).

The scope of the study is limited to the design stage of commercial building projects in Malaysia. The findings are intended to contribute to the strategic application of BIM-LCC integration, promoting long-term cost control, improved decision-making, and enhanced sustainability in the Malaysian construction industry.

II. LITERATURE REVIEW

2.1 OVERVIEW OF LIFE CYCLE COSTING (LCC) IN THE CONSTRUCTION INDUSTRY

Life Cycle Costing (LCC) is a systematic methodology for evaluating the total cost of ownership of a building or infrastructure throughout its entire life span. This includes initial capital investment, ongoing operational and maintenance costs, and final disposal or demolition expenses (Perera et al., 2020). The LCC approach offers solutions for enhanced decision-making through its focus on both original project costs and long-term money flow implications which leads to building lifecycle resource optimization.

LCC offers crucial advantages such that benefit sustainability through selecting energy-efficient solutions and materials as well as predict operational costs with better precision (RICS, 2016; Stonehaven, 2024). LCC serves as an advanced system in big construction projects by enabling comprehensive design choices assessments as well as optimal floor allocation analysis and expected future cost responsibilities estimation (Korte n.d.). Regulatory authorities from various nations make LCC a key component of their green certification systems as they enhance its importance in contemporary construction practices.

2.2 OVERVIEW OF BUILDING INFORMATION MODELLING (BIM) AND ITS ROLE IN COST MANAGEMENT

Building Information Modelling (BIM) functions as an electronic data management system which enables stakeholders to collaborate on creating computational building data descriptions for facility characteristics. BIM helps different stakeholders who include architects and engineers together with quantity surveyors maintain project collaboration through the entire facility lifespan starting from development design the way to demolition (Eastman et al., 2018). BIM enhances decision-making by offering real-time data integration, clash detection, and 3D visualizations, significantly reducing project risks and improving accuracy.

BIM helps cost management through its functionality that enables precise quantity take-offs combined with cost estimations during early design phases. Through advanced BIM systems designers can link databases containing cost information which automatically updates budget estimates when design modifications take place allowing value engineering alongside proactive financial planning according to Azhar (2011) and Zhao et al. (2022). Design information linked dynamically to cost data creates greater transparency which minimizes the risk of cost exploding beyond the budget. The Construction Industry Transformation Programme (CITP) together with initiatives under Construction Revolution 4.0 (CR4.0) in Malaysia positions BIM as a fundamental factor to enhance productivity and innovation for the sector (CIDB Malaysia, 2020). The Malaysian government provides support for BIM adoption, but firms have shown varying levels of implementation. The adoption of BIM faces three main challenges from the combination of inadequate technical abilities and expensive deployment needs and employee opposition—particularly throughout small to medium-sized enterprises (SMEs) (Hashim et al., 2021). BIM development as a cost management methodology a generate long-term value through its alignment with the broader financial approach of Life Cycle Costing (LCC) for sustainability benefits.

2.3 THE USE OF LIFE CYCLE COSTING (LCC) IN BUILDING INFORMATION MODELLING (BIM) AT DESIGN STAGE

Life Cycle Costing integration into Building Information Modelling during design stages creates a preventive system for cost planning optimization of project values. Building Information Modelling allows designers along with quantity surveyors to evaluate long-term material and system economic performance and design alternative costs through BIM model embedded cost data before construction starts (Park et al., 2017). Sustainable

construction decisions become possible through the application of this system because it enables cost evaluations between initial expenses and future operational costs.

Through BIM technology companies can illustrate and study LCC requirements by creating a connection between building elements with cost information systems and life cycle performance indicators. The integration of BIM-LCC helps identify how switching from a lower-cost HVAC system with a better efficient model produces long-term energy savings and reduced payback periods (Kim et al., 2021). The early design decisions in commercial property development benefit greatly from these simulations because they determine operational costs.

The integration of LCC into BIM practices is strongly restricted throughout Malaysia. The expansive adoption of BIM for clash detection and scheduling processes exists alongside weak utilization of its cost management features mainly due to low local LCC expertise together with the absence of standardized processes and inadequate policy regulations (Jamaludin et al., 2023). The resolution of present challenges will allow project teams to make the most of BIM through strategic lifecycle cost efficiency improvements.

2.4 REQUIREMENTS AND DOCUMENTATION FOR ESTABLISHING LIFE CYCLE COSTING (LCC) IN BUILDING INFORMATION MODELLING (BIM)

Integration between Life Cycle Costing (LCC) and Building Information Modelling (BIM) demands systemized input data methods plus unified documentation models together with teamwork strategies. The successful implementation of LCC integration requires practitioners to collect precise and extensive cost information encompassing materials, systems, energy usage, maintenance duration and system replacement schedules. Building elements must exist within the BIM model for these inputs to enable computerized and situation-based lifecycle cost assessments (Perera et al., 2020).

Knowledge transfer for Life Cycle Cost planning occurs through a combination of the Building Information Model (BIM Execution Plan) and Asset Information Requirement (AIR) documents together with the Life Cycle Cost Plan itself. The BIM Execution Plan defines project data exchange protocols together with specification of roles and functions while the AIR establishes required standards for collecting project data during different stages for long-term asset management (BSI, 2013). For optimal compatibility with BIM software and standards LCC data needs to match the Uniformat or Omniclass classification systems.

The standards system under ISO 15686-5 demonstrates complete procedures for LCC calculation and presentation in construction projects. While ISO 15686-5 provides direct guidance on LCC, other BIM-related standards such as ISO 19650 addresses the organization and digitization of information about buildings and civil engineering works, is fundamental in managing information within a BIM environment. The Construction Industry Standard (CIS) 11 released by CIDB Malaysia establishes digital collaboration methods for Construction Revolution 4.0 (CIDB, 2020). The lack of a standardized nation-wide BIM-based LCC implementation guideline in Malaysia produces data fragmentation and securing uniform techniques.

The essential requirement is the implementation of common data environments which combine LCC parameters with Autodesk Revit and Navisworks software and CostX database applications. Real-time updates and enhanced project documentation quality together with better stakeholder visibility occur because of this approach. Complete implementation of LCC-BIM requires continued data improvement through multi-disciplinary collaboration with standard compliance checks.

2.5 BARRIERS AND CHALLENGES IN IMPLEMENTING LIFE CYCLE COSTING (LCC) IN BUILDING INFORMATION MODELLING (BIM)

The Malaysian construction industry faces multiple obstacles which prevent it from adopting Life Cycle Costing (LCC) within Building Information Modelling (BIM) despite its recognized benefits. The main technological hurdle exists in how BIM software platforms fail to work well together with LCC tools. The current BIM software solutions do not include native features for deep lifecycle analysis which necessitates manual or external tools that create workflow complexity according to Zanni et al. (2022). In early design stages the lack of standardized local databases which stores cost and material performance, and service life information leads to unreliable and inconsistent project estimates.

Organizational barriers further constrain implementation. The initial cost focus continued to dominate the mindset of developers and consultants as well as quantity surveyors who demonstrates little motivation to take up LCC strategies (Jamaludin et al., 2023). The shortage of professional training for BIM-LCC convergence practice diminishes the skill sets of building industry personnel and weakens their expertise in this area. Digital cost

planning methods experience slow adoption among senior management because of their resistance to implement changes. Organizations understand LCC advantages, but they stay cautious about embracing new processes since they lack official orders and financial motivations.

A national policy in Malaysia does not exist to mandate LCC implementation within Building Information Modelling (BIM) workflows at the present time. The Construction Industry Transformation Programme (CITP) together with Construction Revolution 4.0 (CR4.0) support digital transformation but project approvals under CIDB (2020) do not require lifecycle cost analysis. National requirements for LCC analysis within BIM workflows remain absent which reduces the necessity for implementation thereby making BIM-LCC integration an optional rather than required practice for sustainable project planning.

III. METHODOLOGY

3.1 RESEARCH DESIGN

This study adopts a descriptive research design to analyze how Life Cycle Costing (LCC) integrates into Building Information Modeling (BIM) practices at the design stage. Descriptive research provides a structured framework for gathering factual industry data without altering variables, allowing for an objective evaluation of LCC adoption among quantity surveyors (John W. Creswell, 2009). By systematically documenting key LCC requirements, tools, and cost estimation approaches within BIM, this study identifies existing practices and sets benchmarks for effective implementation.

Additionally, this research design helps identify key obstacles such as knowledge gaps, training deficiencies, and technological limitations that hinder LCC adoption in BIM. Structured surveys with industry practitioners provide measurable insights that aid in forecasting trends and formulating strategies for better integration. The findings from this research serve as a foundation for future studies and industry applications, ensuring more efficient cost management in construction projects.

Objective 1 is addressed through Section 2.3 of the literature review and validated via Part A of the questionnaire. Objective 2 is achieved through expert input in Part B of the questionnaire. Objective 3 is analysed in Part C, focusing on perceived challenges by professionals.

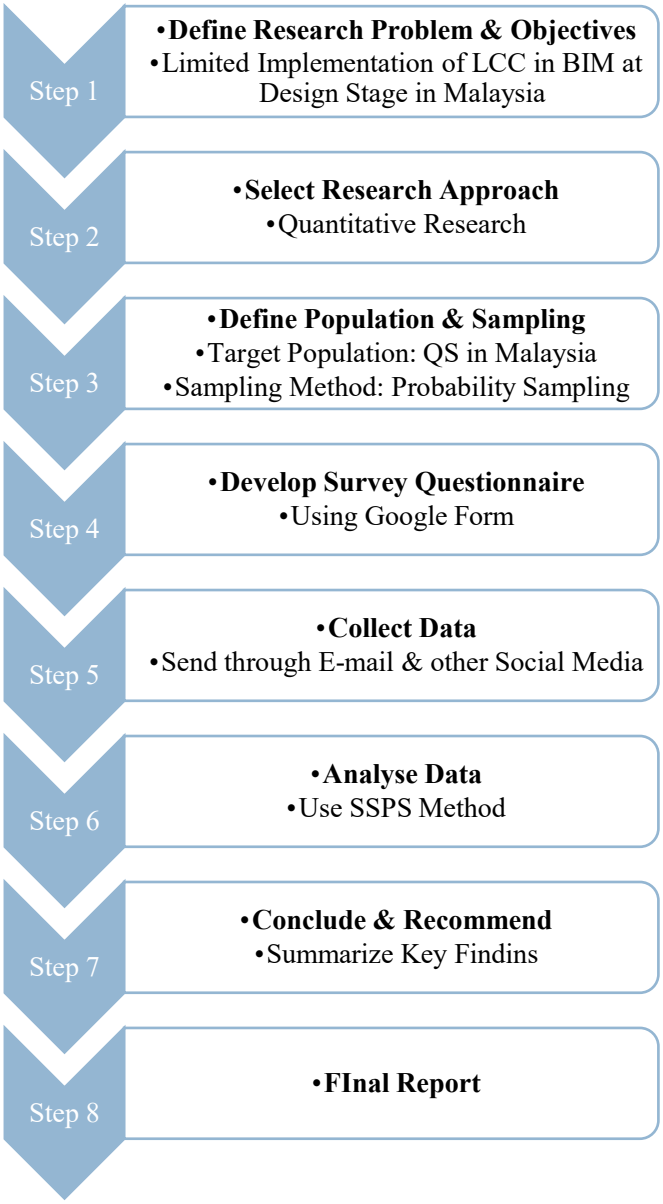


Figure 3.1 shows steps in conducting the research.

3.2 RESEARCH METHOD: QUANTITATIVE APPROACH

This study adopts a quantitative research approach to gather numerical data and analyze BIM Life Cycle Costing (LCC) adoption among quantity surveyors through structured surveys. This method ensures uniform data collection, enabling statistical analysis to identify trends and correlations within the industry (Divya Sreekumar, 2023).

Quantitative research is chosen for its objectivity, scalability, and ability to minimize researcher bias, making findings applicable to broader populations (Pritha Bhandari, 2020). Structured survey instruments provide measurable data, ensuring validity and reliability through statistical tests (Langos, 2014). This approach efficiently tracks industry trends, allowing comparisons across demographics to identify key factors influencing LCC adoption.

3.3 POPULATION AND SAMPLING

A clear understanding of population and sampling is crucial in research methodology as it determines data collection and analysis. The research population includes all subjects relevant to the study, while the target population refers to a specific subgroup that aligns with research criteria (Polit and Hungler, 1999). Defining the

study population at the outset ensures validity by establishing clear participant requirements and guiding sampling techniques.

Sampling involves selecting a representative subset from the population to draw conclusions without surveying everyone. Researchers use probability sampling for known selection probabilities and non-probability sampling for subjective selection. The chosen method impacts research reliability and validity. A well-defined population and appropriate sampling technique ensure accurate data collection and meaningful findings (Riya Thomas, 2023).

Target Population

The study targets quantity surveying professionals involved in cost management and construction decision-making, specifically from four groups: Government Agencies, Developers, Consultant Firms, and Contractors. Government agencies oversee budgets and financial plans, while developers ensure project financial viability. Consultant firms provide specialized cost estimation services, and contractors apply LCC methodologies during execution (Lee, 2019) These professionals are crucial due to their active role in cost management and the integration of BIM and LCC in modern construction practices, enhancing project accuracy and efficiency.

Sampling Method

This study employs purposive sampling, a non-probability approach, to select quantity surveyors and cost consultants with experience in BIM and LCC within Malaysia's construction sector. This method ensures that only knowledgeable professionals contribute, providing relevant insights. A minimum of fifty respondents is targeted to achieve statistical significance while maintaining manageable data collection (Goundar, 2012). Participants must meet three criteria: active practice in the construction industry, experience with BIM and LCC, and involvement in Malaysia's construction sector, ensuring the data accurately reflects expert perspectives.

3.4 QUESTIONNAIRE DEVELOPMENT

This research develops a structured questionnaire to gather insights on BIM and LCC integration among Malaysian quantity surveyors. Google Forms is chosen for its accessibility, ease of use, and automated data management, improving response rates and data analysis efficiency (Pritha Bhandari, 2020; Regmi et al., 2016). The questionnaire is designed based on literature reviews and expert feedback to ensure reliability and validity. It also to was designed to fulfill three objectives stated in the introduction. It consists of four sections: Section A collects demographic details, Section B examines LCC integration in BIM during the design stage, Section C identifies essential elements for effective LCC implementation, and Section D explores challenges faced in BIM-based LCC adoption, including technical, financial, and regulatory barriers.

A five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) is used for structured responses, while open-ended questions allow respondents to share additional perspectives. The systematic questionnaire design ensures comprehensive data collection, helping to address current industry challenges and guide future improvements in LCC-BIM integration.

3.5 DATA COLLECTION

This research targets Malaysian quantity surveyors, a key professional group in the construction sector, as they play a crucial role in cost estimation and financial planning, making them essential for LCC implementation at the design stage (Bin et al., 2020). Respondents selected are from government agencies, developers, consultants, and contractors to provide diverse industry insights (Osman et al., 2015). Only those with experience in LCC and BIM will be considered, identified through professional connections and institutional databases (Ismail et al., 2019). Data collections are conducted via structured online surveys using Google Forms, distributed through email, WhatsApp, LinkedIn, and Facebook to maximize engagement. The online format enhances accessibility, efficiency, and cost-effectiveness while allowing busy professionals to participate conveniently. The survey period spans one month to ensure comprehensive responses reflecting industry perspectives on BIM and LCC adoption in Malaysia.

3.6 DATA ANALYSIS

The systematic analysis of numbers constitutes quantitative data examination to obtain valuable interpretations which lead researchers toward meaningful conclusions. Quantitative research follows multiple standardized sequential steps for data analysis. Numerical data collection occurs during the first stage through structured instruments such as surveys or experiments. Data cleaning procedures ensure the accuracy of data through error and inconsistency removal. The process of data analysis functions through statistical approaches to establish understanding from collected data. Data visualization represents the findings through graphical representations and tabular arrangements to promote understanding (Pritha Bhandari, 2020).

Data is analysed using **SPSS** software. Descriptive statistics summarize frequencies and means, while inferential techniques such as reliability tests and cross-tabulations support deeper analysis. The findings present map directly to each research objective to ensure clarity in interpretation.

CONCLUSION

Research examines Life Cycle Costing (LCC) deployment for design purposes through Building Information Modeling (BIM) across Malaysia. The quantitative evaluation method reveals the extent of LCC implementation alongside needed documents and requirements and implementing obstacles within BIM practices. Research results indicate that LCC shows potential benefits for improving both operational costs and organizational decisions alongside solutions to deal with barriers stemming from limited data accessibility and limited industry expertise and hardware implementation challenges. This research offers industry professionals information to improve cost management by developing BIM-based LCC methods. The findings are expected to provide guidelines for integrating LCC into BIM workflows at the design stage, enhance cost control practices, and inform policy recommendations for digital transformation in construction.

ACKNOWLEDMENTS

The author acknowledges the guidance and support provided by the supervisor, Sr. Dr. Hasnanywati Hassan, a corresponding author from Universiti Sains Malaysia, Pulau Pinang, Malaysia.

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COMPARING AI AND HUMAN STRATEGIES IN MANAGING CONSTRUCTION DELAYS

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ABSTRACT

Construction delay is a common issue in the construction sector, leading to cost overruns, prolonged project duration and strained stakeholder relationships. Conventional delay management measures based on human experience and instinct are inadequate in addressing the complexity of today's construction projects. The introduction of Artificial Intelligence (AI) has provided the possibility for improved delay management through data-based knowledge, predictive analysis and real-time tracking. The aim of this study is to compare AI-based and conventional human strategies in managing construction delays with emphasis on delay detection, mitigation, and recovery planning. This study adopts a mixed-mode approach in which data are collected using questionnaire surveys and in-depth interviews with project managers, construction managers, and project planners. The study compares the effectiveness of AI strategies to human strategies and establishes differences in their approaches. Findings substantiate that AI has profound benefits in predictive analysis, resource use and real-time tracking, when it comes to proactive delay management. Yet AI cannot replace human knowledge in scenarios where contextual acumen, bargaining and emotional intellect are needed, especially in dealing with stakeholder relations and field conditions adaptation. Conclusions are that synergy whereby the data-intensive strength of AI and human knowledge and instincts combined can yield the best solution in construction delay management. This research contributes to the existing literature on AI application in construction management with practical recommendations for industry players and policymakers. The study points out the potential of AI to drive successful projects while observing the continued need for human intuition in decision-making on complicated matters. This research offers recommendations for further studies, including ethical issues involved in the use of AI as well as the training requirements for effective AI implementation in construction projects

Keywords: Construction Delay, Artificial Intelligence (AI), Delay Management

I. INTRODUCTION

Construction delays are a persistent issue globally, impacting time, cost, and quality in project delivery. These delays often stem from factors such as inadequate planning, labor shortages, unforeseen site conditions, and poor communication among stakeholders. Traditional delay management relies heavily on the experience and judgment of project managers, which, while valuable, is prone to human limitations, such as bias and delayed decision-making.

With the advent of artificial intelligence (AI), there is growing interest in its potential to transform how delays are identified, analysed, and mitigated. AI systems can process vast datasets and generate real-time insights, potentially offering more objective and predictive solutions than conventional human-led strategies. However, the effectiveness and reliability of AI-based approaches compared to human strategies remain underexplored in construction management literature.

This conceptual paper aims to explore and compare AI-driven strategies with traditional human approaches in managing construction delays. By outlining a research framework and expected outcomes, this paper lays the groundwork for future empirical studies that may support more effective and intelligent project delay management practices.

1.1 Problem Statement

The construction industry (CI) is a cornerstone of economic and social development, contributing to infrastructure delivery, job creation, and technological advancements (Baccarini, 1996). However, construction projects are inherently complex, involving multiple stakeholders, significant financial investments, and extended timelines. The interconnected nature of construction projects means that even minor setbacks can disrupt the overall progress and lead to delays, which in turn result in increased costs, missed deadlines, and strained relationships among stakeholders (Baccarini, 1996). Despite extensive efforts by experienced project managers who rely on intuition, experience, and decision-making skills, delays remain a persistent challenge in the construction industry. These delays often lead to cost overruns and the failure to meet project timelines. Traditional delay management strategies, while effective in some contexts, are not always sufficient to address the increasing complexity and scale of modern construction projects.

Many industry participants are contemplating the adoption of AI but may not fully understand its potential benefits or drawbacks in comparison to traditional methods. While AI is widely used in data management within the construction sector, its application for delay management remains underexplored, potentially due to a lack of awareness or the perception that AI is irrelevant to this aspect of construction management. Despite the growing adoption of AI technologies, the awareness of AI's potential to mitigate project delays remains limited among construction professionals (Abioye et al., 2022). Although AI shows great promise in data analysis and pattern recognition, its role in delay management is still being assessed. AI may not fully replicate human capabilities in areas requiring contextual understanding, negotiation, and emotional intelligence. For instance, managing stakeholder conflicts or adapting to unforeseen site conditions requires a human touch, which AI cannot replace (Shirowzhan et al., 2021). Therefore, it is crucial to investigate whether AI can complement human expertise in managing delays, enhancing efficiency without displacing human judgment.

This research seeks to evaluate AI-driven delay management strategies against traditional methods employed by experienced construction professionals. By identifying key differences in delay identification, mitigation, and recovery planning between AI-generated and human responses, this study aims to contribute valuable insights into how AI and human strategies can complement each other in construction delay management.

II. LITERATURE REVIEW

The construction industry (CI) is a key contributor to economic growth, playing a crucial role in infrastructure development, job creation, and technological advancements (Gurumayum, 2025). Despite its importance, construction projects are often delayed by factors such as design changes, material shortages, and poor site management (Gurumayum, 2025). Traditional delay management strategies, which largely rely on human judgment and experience, are often insufficient in addressing these challenges effectively. As a result, the construction sector is increasingly adopting Artificial Intelligence (AI) as an innovative solution to mitigate these limitations. AI technologies, such as predictive analytics, real-time monitoring, and automated decision-making, offer promising opportunities to improve project efficiency and reduce delays (Choudhury & Paul, 2025). The transition from traditional methods to AI-based approaches represents a significant advancement in proactively managing construction delays.

2.1 Challenges and Factors Contributing to Project Delays

Unforeseen events such as design changes and adverse weather conditions often disrupt construction project schedules and budgets (Harrison & Lock, 2020). Additionally, the construction industry's fragmented structure, which involves multiple contractors, subcontractors, and consultants, creates inefficiencies that hinder the smooth execution of projects. The increasing complexity of construction projects, coupled with external pressures such as regulatory compliance and sustainability demands, highlights the need for more innovative management strategies. AI can address many of these challenges by providing predictive insights, automating routine tasks, and supporting improved decision-making, ultimately enhancing the overall project management process.

Several factors contribute to delays in construction projects, as highlighted in recent academic studies in Table 2.1. Design and planning issues, such as poor site management and frequent design changes, are frequently cited as primary causes of delays (Aziz et al., 2020; Al-Hazim et al., 2021). Material shortages and equipment breakdowns also frequently lead to project delays (Ullah et al., 2020; Khan et al., 2022). Environmental factors, including adverse weather and unforeseen site conditions, can significantly impact project schedules (Zhang & Lee, 2021; Othman et al., 2023). Furthermore, delays are often exacerbated by disputes among workers, delays in administrative tasks like approvals and permits, and financial constraints (Shafique & Mahmood, 2022; AP News, 2020). Supply chain disruptions further contribute to delays, highlighting the critical need for effective project management (Rahman et al., 2021; Ahmad et al., 2020; Deloitte, 2020).

Table 2.1: Factors Contributing to Construction Delays

Category	Factor	Reference
Design and Planning Issue	Design Changes	Aziz et al. (2020)
	Poor Site Management	Al-Hazim et al. (2021)
Resource and Equipment Shortage	Resource Shortages	Khan et al. (2022)
	Equipment Failures	Ullah et el. (2020)
External and Environment Factors	Weather Conditions	Zhang & Lee (2021); Othman et al. (2023)
	Unforeseen Site Conditions	Love et al. (2002)
Labour and Stakeholder Conflicts	Labor Disputes	Shafique & Mahmood (2022)
	Regulatory Delays	AP News (2020)
Financial and Supply Chain Issues	Financial Issues	Rahman et al. (2021); Ahmad et al. (2020)
	Supply Chain Disruptions	Deloitte (2020)

2.2 Strategies to Overcome Construction Delays

Delays in construction projects have long been a significant challenge in project management, and effective strategies are essential for minimizing their impact. Both traditional and modern approaches are used to identify, address, and recover from delays. Traditional methods, such as real-time monitoring, human-driven procedures, and AI-assisted techniques, are commonly applied in the construction industry. Several strategies have been proposed to mitigate delays, including buffer time planning, contingency planning, and creative scheduling methods, which help to minimize disruptions (Zhao et al., 2020; Petzold et al., 2022; Kerzner, 2021). When faced with insufficient resources or equipment, solutions such as resource redeployment and improved material and supply chain management can facilitate smoother project execution (Alaghbari et al., 2021; Doloi et al., 2020). For external issues such as weather or environmental conditions, forward planning and accelerated schedules are suggested as effective countermeasures (Wang et al., 2022). Additionally, financial challenges and labour disputes can be mitigated through better contract management, stakeholder communication, regular progress monitoring, and training programs (Love et al., 2023; Ochieng & Price, 2020; Patel et al., 2024; Jarkas & Bitar, 2021). Client-related delays, such as late approvals, design changes, and payment issues, also significantly affect project timelines and workflow. Table 2.2 shows the strategies to overcome construction delays by previous research.

Table 2.2: Strategies to overcome construction delays

Category	Strategy	Reference
Design and Planning Issue	Buffer time planning	Zhao et al., (2020).
	Contingency Planning	Petzold et al., (2022).
	Revised Scheduling Techniques	Kerzner, (2021)
Resource and Equipment Shortage	Resource Reallocation	Alaghbari et al., (2021).
	Material and Supply Chain Management	Doloi et al., (2020)
External and Environment Factors	Accelerated Work Schedules	Wang et al. (2022).
Labour and Stakeholder Conflicts	Improved Contract Management	Love et al., (2023)
	Effective Communication Among Stakeholders	Ochieng & Price, (2020)
Financial and Supply Chain Issues	Regular Progress Monitoring	Patel et al., (2024)
	Training and Skilled Workforce Development	Jarkas & Bitar, (2021)

2.3 Artificial Intelligence in Construction Management

Artificial Intelligence (AI) is gradually reshaping the construction management process, particularly in the areas of project planning, execution, and management. AI technologies enhance decision-making, improve efficiency, and foster proactive problem-solving, especially in managing delays. By analysing vast amounts of data, AI can uncover insights that might be overlooked by human experts. For example, AI can predict potential delays by examining historical project performance data, allowing project managers to take preventative actions (Bogue, 2021). This section discusses the integration of AI in construction management, its applications, benefits,

challenges, and relevant case studies. AI plays a significant role in mitigating delays at various stages of construction management. In delay identification, AI systems can analyse project schedules and detect deviations that may lead to delays. Machine learning models, for example, can identify constraints in resource availability or productivity issues in real-time (Zhao et al., 2020). AI also contributes to scheduling optimization by running simulations of different activity sets to determine the optimal path for avoiding delays. Tools like Primavera P6, integrated with AI algorithms, are used to enhance scheduling accuracy and efficiency (Sun et al., 2023). In recovery planning, AI suggests alternative strategies for resource allocation, task reordering, or workflow adjustments to minimize delays. Predictive models offer recovery tactics that cause minimal disruption to the overall project (Lee et al., 2022).

Despite the potential benefits, several barriers hinder AI adoption in the construction industry. High implementation costs are a significant challenge, as developing and deploying AI systems require substantial financial investment. This may be particularly burdensome for smaller companies with limited budgets (Zhao et al., 2020). Resistance to change is another obstacle, as many construction workers are unfamiliar with new technologies and may fear job displacement (Gheisari & Irizarry, 2021). Furthermore, data security and privacy concerns are critical, as AI systems rely on large datasets, which raise risks of cybersecurity breaches (Lee et al., 2022). Lastly, the shortage of skilled professionals in data science and machine learning further impedes the widespread adoption of AI in the construction sector (Petzold et al., 2022). Among the AI technologies used to mitigate construction delays, ChatGPT offers a unique advantage in comparison to human project managers. Unlike human managers, ChatGPT is available 24/7, providing immediate responses and consultations on potential delays. It can analyse vast amounts of data and provide insights based on historical trends, best practices, and project performance (Choudhury & Paul, 2025). ChatGPT can also handle multiple queries simultaneously, making it particularly useful for large projects with many stakeholders. However, while ChatGPT can provide standardized and coherent responses, human intuition and contextual judgment are still necessary in complex, nuanced situations where AI may lack depth (Shirowzhan et al., 2021). Thus, while AI can assist in delay management, it complements rather than replaces human expertise.

III. RESEARCH METHODOLOGY

This conceptual paper employs a convergent parallel mixed-method design, integrating quantitative and qualitative approaches conducted concurrently to examine and compare the effectiveness of artificial intelligence (AI) versus traditional human methods in managing construction project delays. This design enables a comprehensive analysis by capturing both broad numerical trends and in-depth contextual insights, which are later integrated to draw meaningful conclusions. This study is guided by the following objectives: (1) To to evaluate AI strategies for managing construction project delays against experienced construction players, and the second objective (2) is to to compare between AI-generated responses and construction players in managing project delays, such as ChatGPT, with those of human practitioners in identifying, mitigating, and recovering from construction project delays. The study focuses on Grade G7 contractors registered with CIDB Malaysia, specifically those operating in the Johor and Selangor regions. These contractors can execute projects with unlimited value and complexity, making them ideal subjects for exploring delay management strategies in large-scale construction projects. The primary respondents are senior-level construction professionals, such as project managers, construction managers, and project planners, who play critical roles in project planning, execution, and delay resolution.

3.1 Research Design and Data Collection

Using a convergent parallel design, the study collects quantitative and qualitative data simultaneously but independently. The rationale for this design lies in the need to compare generalizable patterns from a larger sample with rich, detailed insights from key informants—allowing both data types to complement and validate one another during interpretation. For the quantitative component, a structured online questionnaire will be distributed among professionals involved with G7 contractors in Johor and Selangor. The study draws from a population of 4,424 registered G7 contractors, as listed on the CIDB Malaysia database. A stratified purposive sampling strategy ensures diverse representation across different professional roles and firm types. For the qualitative component, semi-structured in-depth interviews will be conducted with a purposive sample of senior professionals from the same cohort. The interviews aim to explore practical experiences, decision-making processes, and the perceived effectiveness of both AI tools and traditional human strategies in managing construction delays.

3.2 Data Analysis

Quantitative data will be analysed using descriptive statistics and the Kruskal-Wallis H test to identify statistically significant differences in perspectives across professional roles and regions regarding delay management practices and AI integration. Qualitative data will undergo thematic analysis based on Braun and Clarke's (2006) framework. This process involves data familiarization, coding, theme development, and interpretation to reveal patterns, challenges, and contrasts in professional strategies, particularly in relation to AI-supported decision-making tools such as ChatGPT. Following analysis, both data sets will be merged for interpretation, where convergences or divergences between quantitative trends and qualitative insights will be examined. This integration helps validate the findings, enrich interpretations, and enhance the overall reliability of the study.

IV. EXPECTED FINDING

For the first objective, the study is expected to reveal the comparative effectiveness of AI in managing construction delays relative to human expertise. It is anticipated that AI will demonstrate greater efficiency and consistency in performing specific tasks such as identifying delays early, responding swiftly to scheduling deviations, and reallocating resources to minimize disruption. These capabilities are likely to be attributed to AI's ability to process large datasets and provide real-time insights that can enhance decision-making. However, the findings may also indicate that human professionals excel in areas requiring contextual awareness and adaptive thinking. For example, when construction projects encounter unique, unforeseen site conditions or require nuanced stakeholder negotiation, experienced managers may offer more flexible and tailored solutions. The outcome of this objective should help delineate the distinct strengths and limitations of both AI and human approaches and identify the areas where AI can either replace or augment human judgment in delay management.

Regarding the second objective, the research is expected to uncover notable differences in how AI systems and human professionals frame problems and make decisions when managing project delays. Human respondents may exhibit a stronger emphasis on strategic and adaptive mitigation planning, often shaped by past experiences and situational judgment. In contrast, AI's logic is likely to remain structured and data-driven, which can be effective in pattern recognition but potentially less responsive to complex, site-specific challenges. Through thematic analysis of interviews, the study may highlight underlying themes such as the level of trust in AI recommendations, the value placed on human intuition and professional judgment, and the ways in which AI is currently perceived by industry players. Ultimately, these outcomes are anticipated to support the notion that AI should not be seen as a replacement for human roles, but rather as a complementary tool that can enhance the capacity of professionals in managing delays more effectively and strategically in the construction industry.

CONCLUSION

This conceptual paper has explored the integration of artificial intelligence (AI) in managing construction project delays, particularly in comparison to traditional human-driven approaches. By employing a convergent parallel mixed-method design, the study aims to evaluate the strengths and limitations of both AI and human strategies in addressing delay-related challenges. Preliminary expectations suggest that AI may outperform humans in tasks requiring speed, consistency, and data analysis, while human professionals bring essential context-specific judgment and adaptability. Ultimately, the study aspires to demonstrate how a synergistic application of both AI and human intelligence can lead to more effective delay management and improved project outcomes in the construction industry.

ACKNOWLEDGMENT

The author wishes to thank the organizing committee of ISCU2025 for the opportunity to present this conceptual work. Appreciation is also extended to academic mentors and industry professionals whose preliminary feedback and insights have shaped the direction of this research. Furthermore, I would like to thank the Department of Quantity Surveying, Faculty of Built Environment and Surveying, for granting me an opportunity to present the paper in this conference.

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THE POTENTIAL OF VIRTUAL REALITY AND BUILDING INFORMATION MODELLING INTEGRATION IN UNLOCKING THE FUTURE OF COST ESTIMATION

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ABSTRACT

Cost estimation is a crucial element in construction project management, influencing budgeting, resource allocation, and decision-making. Traditional methods relying on 2D drawings and manual calculations often result in inefficiencies and errors. Building Information Modelling (BIM) has improved accuracy in cost estimation through automated quantity take-offs and 3D visualization. Integrating Virtual Reality (VR) with BIM has the potential to enhance cost estimation by providing an interactive and immersive experience, enabling stakeholders to better understand design elements and cost implications. This research aims to investigate the potential of integrating VR technology into BIM-based cost estimation and the key challenges in integrating VR with BIM for cost estimation. A qualitative method is used, involving semi-structured interviews with industry professionals experienced in BIM, cost estimation, and VR. The data will be analyzed through thematic analysis. The findings are expected to offer valuable insights into enhancing cost estimation accuracy and efficiency through VR-BIM integration, providing practical recommendations for industry practitioners. Ultimately, this research aims to contribute to advancing digital construction practices, improving stakeholders' collaboration on the full potential of VR-BIM integration, and supporting better decision-making in cost estimation.

Keywords: Cost Estimation, Digital Construction, Virtual Reality (VR), Building Information Modelling (BIM)

I. INTRODUCTION

Effective financial planning is critical to the successful completion of construction projects, as it directly influences budgeting, resource allocation, and overall project outcomes. However, traditional cost estimation techniques often struggle to keep up with the increasing demands of modern construction projects, where precision, adaptability, and efficiency in budgeting and resource management are essential. According to Azhar (2011), traditional methods that rely on 2D drawings and manual calculations tend to be inefficient, time-consuming, and prone to human error. These limitations often result in inaccurate cost predictions, budget overruns, and project delays, ultimately undermining the project's success (Azhar, 2011).

Building Information Modelling (BIM) has significantly advanced the field of cost estimation by automating processes such as quantity takeoffs and offering 3D visualization of projects. BIM allows for a more accurate and efficient representation of the project, facilitating better decision-making and coordination among stakeholders (Lee et al., 2022). The integration of Virtual Reality (VR) with BIM offers a promising solution to these challenges. VR provides an immersive, interactive 3D experience that allows stakeholders to engage with the project in a more intuitive and collaborative manner. This interaction can improve communication, enhance stakeholder understanding, and ultimately support better decision-making throughout the project lifecycle (Tung et al., 2021). By enabling real-time, immersive interaction with BIM models, VR has the potential to significantly improve the accuracy of cost estimation and reduce the likelihood of costly errors (Safira et al., 2024).

II. LITERATURE REVIEW

A. BIM-Based Cost Estimation

Cost estimation (CE) in construction is a critical process that influences project feasibility, budgeting, and financial planning. Traditional CE methods rely on 2D drawings and historical data, which may not fully capture project complexities, leading to cost overruns and discrepancies between estimated and actual expenses. In contrast, Building Information Modelling (BIM)-based CE offers a more integrated and automated approach, improving accuracy, efficiency, and collaboration among stakeholders (Azhar, 2011). By providing a digital representation of a project's physical and functional aspects, BIM enhances accuracy, reduces manual errors, and improves collaboration among project stakeholders. Recent research highlights the potential of predictive analytics and machine learning in further refining early-stage cost forecasts, enabling more informed financial decision-making even with minimal initial design information (Castro Miranda et al., 2022).

The integration of BIM-based CE within structured project management frameworks, such as the RIBA Plan of Work 2020, has significantly improved cost control throughout the construction lifecycle. At the early stages, broad estimation methods like parametric estimation and square meter rate calculations provide initial cost projections, while more detailed approaches, such as Elemental Cost Breakdown and Bill of Quantities (BQ), refine estimates as the design progresses. These evolving methodologies ensure more accurate financial planning and resource allocation. Additionally, real-time financial tracking tools, such as Earned Value Management (EVM), allow stakeholders to monitor costs against project milestones, promptly addressing budget deviations to maintain financial stability (Yang et al., 2022).

In Malaysia, the adoption of standardized cost estimation practices, such as the Standard Method of Measurement (SMM) for BQ preparation, has aligned well with BIM implementation which enhances the cost accuracy and contractor bidding processes (CIDB, 2022). BIM's ability to integrate cost data with design modifications increases financial transparency and reduces the risks of budget overruns or unexpected expenses. As digital transformation continues to shape the construction industry, BIM-based CE is becoming an essential tool for achieving data-driven, efficient, and reliable cost management. Its growing adoption reflects a shift toward more proactive financial planning, ultimately supporting the successful delivery of projects within budget and schedule constraints.

B. Virtual Reality (VR) and Building Information Modelling (BIM) application in Construction Industry

The integration of Virtual Reality (VR) with Building Information Modelling (BIM) is revolutionizing the construction industry by improving project visualization, collaboration, and decision-making. BIM serves as a comprehensive digital framework that provides highly detailed 3D models enriched with essential project data, including material specifications, quantities, construction sequencing, and timelines. When combined with VR, these models transform into immersive environments where stakeholders can interact with designs in real-time. This integration bridges the gap between digital planning and actual construction, allowing architects, engineers, and clients to explore and assess designs in a more intuitive and interactive manner than traditional 2D drawings or static 3D models. Research suggests that VR-BIM integration enhances design accuracy, minimizes errors, and improves stakeholder engagement, leading to more efficient project delivery (Zhang et al., 2020).

BIM technology has evolved beyond basic 3D modelling to include additional dimensions that enhance various aspects of construction management. The fourth dimension (4D) incorporates time-related data, allowing for construction sequence simulations and improved scheduling. The fifth dimension (5D) integrates cost estimation, linking material quantities to real-time pricing for better budget control and reduced financial risks. The sixth dimension (6D) focuses on sustainability, enabling energy performance analysis and environmentally friendly design considerations. Lastly, the seventh dimension (7D) supports facility management by providing digital records for asset maintenance and lifecycle planning. Together, these dimensions offer a comprehensive approach to construction, ensuring greater efficiency from project inception to post-construction operations (Fazeli et al., 2020).

The effectiveness of VR in construction is shaped by its core dimensions with visual, auditory, and kinesthetic interaction. The visual aspect allows users to navigate and experience BIM models through VR headsets, offering a realistic representation of spatial relationships, material finishes, and structural components. This immersive visualization helps in early design evaluation and clash detection, reducing the likelihood of costly revisions later in the project. The auditory dimension further enhances realism by incorporating environmental sounds, machinery noise, and acoustic simulations, which assist in assessing design impacts in real-world conditions (Kim & Lee, 2022). Additionally, the kinesthetic dimension allows users to interact physically with the virtual environment using motion tracking and haptic feedback, enabling them to simulate construction

activities such as material placement or equipment operation. These interactive capabilities not only improve design accuracy but also enhance training programs and safety assessments for construction teams (Mubarrat et al., 2024).

The use of VR tools in the construction industry has significantly improved design visualization, training, and collaboration. Head-mounted displays (HMDs) such as the Oculus Rift, HTC Vive, and Microsoft HoloLens enable architects, engineers, and clients to explore and interact with 3D building models in real time, facilitating more effective design reviews and stakeholder communication. Additionally, haptic feedback gloves like the HaptGlove enhance training by allowing users to simulate physical interactions with virtual objects, making tasks such as structural assembly and equipment operation more immersive. While high-end VR devices can be expensive, more affordable alternatives like the Meta Quest 2 and Pico VR headsets are increasing accessibility, allowing small and mid-sized construction firms to adopt VR technology.

To effectively implement VR-BIM integration, a well-established technological infrastructure is required including BIM-authoring software such as Autodesk Revit and ArchiCAD, VR platforms like Unity and Unreal Engine, and cloud-based collaboration tools that enable real-time data sharing. Cloud computing plays a crucial role in facilitating seamless integration, allowing project teams to access and modify BIM models remotely. However, challenges such as software interoperability, high implementation costs, and a lack of standardized practices remain obstacles to widespread adoption. Overcoming these challenges through industry-wide training, improved data exchange protocols, and cost-effective solutions will be essential for maximizing the benefits of VR-BIM applications in cost estimation, project planning, and facility management (Eldin et al., 2024). As technology continues to advance, the integration of VR and BIM is expected to become even more accessible and impactful, driving innovation and efficiency in the construction industry.

C. Challenges of VR integration in Construction Project

The integration of Virtual Reality (VR) with Building Information Modelling (BIM) offers a transformative potential for the construction industry, enhancing workflows, improving visualization, and fostering better collaboration. However, several significant challenges prevent the widespread adoption of VR-BIM technologies, particularly in terms of technical, financial, and organizational barriers. One of the most prominent obstacles is the high cost associated with implementing VR-BIM systems. The expense of advanced VR devices, such as head-mounted displays (HMDs) and motion controllers, as well as the powerful computing systems required, can be overwhelming for smaller construction firms. In addition, the specialized software needed for BIM-VR integration often comes with steep licensing fees, making it even harder for firms, especially those in developing countries with limited budgets, to access these technologies (Zainuddin et al., 2024).

From a technical standpoint, achieving seamless compatibility between BIM software and VR platforms is a significant challenge. Converting detailed BIM models into formats that work well with VR often leads to data loss, particularly with material textures, lighting, and annotations. This reduces the effectiveness of VR simulations, making them less reliable for decision-making and planning. Large-scale BIM models also demand considerable computational power to be rendered in real time, which can result in lag, system crashes, or poor frame rates. These technical limitations hinder the scalability of VR-BIM systems, making them less suitable for large construction projects where precision and efficiency are crucial (Lin et al., 2020). Moreover, performance limitations can interfere with essential tasks such as clash detection and construction sequencing, which are vital for ensuring successful project delivery.

Another significant barrier to the adoption of VR-BIM is the lack of skilled professionals who are proficient in both VR technology and BIM modeling. The construction industry faces a notable skills gap, with many workers lacking the technical expertise needed to fully utilize these advanced tools. Bridging this gap requires substantial investment in training programs, which are both time-consuming and costly. This challenge is especially evident in regions with limited access to technical education and training opportunities (Abbasnejad et al., 2022). Additionally, the conservative nature of the construction industry and the resistance to change further complicate the adoption of VR-BIM. Many stakeholders remain skeptical about the long-term benefits and return on investment (ROI) of these technologies, which slows down the integration process (Ahmed, 2020).

Data security concerns related to cloud-based platforms used for VR-BIM integration also present a significant challenge. Construction projects often involve sensitive information, such as proprietary designs, client data, and project costs, all of which are vulnerable to cyberattacks. Without strong cybersecurity measures, companies are understandably reluctant to adopt VR-BIM technologies. These concerns are amplified in developing countries with inadequate infrastructure, including unreliable internet connectivity and limited access to VR hardware. These challenges make it difficult to deploy cloud-based VR applications and facilitate real-time

collaboration, which are essential for realizing the full potential of VR-BIM systems. Overall, these challenges highlight the complexity of integrating VR and BIM in the construction industry and underscore the need for strategic interventions to address these barriers (Safira et al., 2024).

III. METHODOLOGY

This research adopts a qualitative research design to gain a deeper understanding of the perspectives of industry experts on the integration of Virtual Reality (VR) and Building Information Modelling (BIM) in cost estimation. Qualitative research is well-suited for this type of investigation, as it allows for the exploration of complex, subjective experiences and the discovery of emerging trends. As noted by Creswell (1994), qualitative research follows an inductive approach, where theories and insights are allowed to develop throughout the research process based on the data collected. This approach aligns with the goals of this study, which seeks to explore new insights into VR-BIM integration, rather than testing pre-existing theories. Semi-structured interviews were chosen as the main method of data collection because they strike a balance between structure and flexibility. This format allows interviewees to freely share their thoughts while keeping the conversation focused on the research objectives (Roberts et al., 2023). By using a qualitative design, the research aims to capture rich, in-depth insights that provide a clearer picture of the opportunities and challenges in the adoption of VR and BIM within the construction industry.

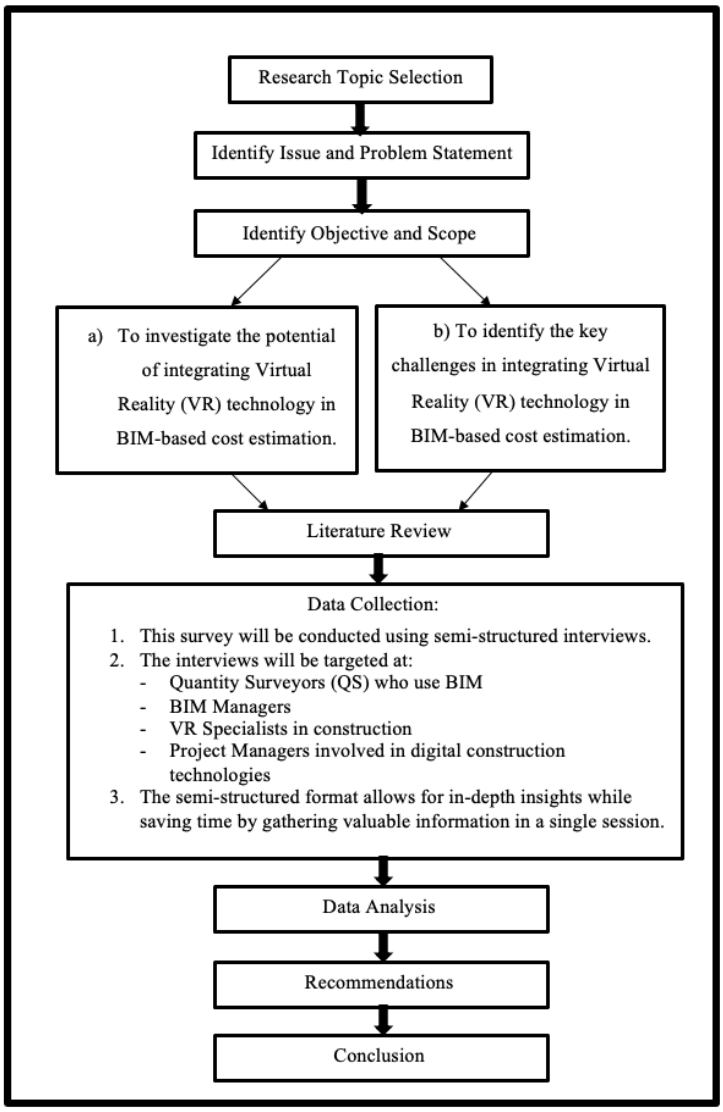


Figure 1.0 Research Method Process

A. Instrument Development

The design of the research instrument is carefully aligned with the findings from the literature review to

ensure that the questions are both relevant and effective in addressing the key research objectives. The instrument focuses on capturing the demographic details and professional expertise of participants, particularly in their experience with integrating Virtual Reality (VR) into Building Information Modelling (BIM) for cost estimation. As highlighted in the literature, VR integration in BIM for cost estimation is still a developing field, and exploring both the potential and challenges from the perspective of industry professionals will provide valuable insights into its practical applications (Zainuddin et al., 2024). By focusing on these areas, the instrument aims to gather comprehensive data that reflects the current state of VR-BIM integration in the industry.

The semi-structured interview format chosen for this research allows for an open and flexible discussion, encouraging interviewees to share detailed insights while ensuring the conversation remains focused on the research objectives. This approach aligns with Creswell's (1994) inductive methodology, which emphasizes the emergence of theory through data rather than testing preconceived hypotheses. The interview guide is divided into sections that directly address the research objectives by exploring the potential of VR in BIM-based cost estimation and identifying the challenges associated with its integration. By examining the experiences and perspectives of experts, the research aims to uncover both the opportunities and barriers to successful VR-BIM integration, which are crucial factors identified in the literature as limiting broader adoption (Lin et al., 2020; Safira et al., 2024).

B. Population and Sampling

In this research, purposive expert sampling is used to ensure that the data gathered comes from individuals who possess specific, in-depth expertise in areas relevant to the research. This method is particularly useful when seeking insights from professionals who have extensive experience in fields like Quantity Surveying (QS), Building Information Modelling (BIM), and Virtual Reality (VR) in construction. The use of expert sampling aligns with previous research that emphasizes the value of gathering information from those with specialized knowledge, especially when exploring complex and emerging technologies like VR integration in BIM-based cost estimation (Creswell, 1994). Respondents were carefully selected based on their active involvement in using or managing BIM systems or applying VR technologies in the construction industry, ensuring they have the necessary expertise to provide meaningful and informed insights.

The participants in this study include professionals in key roles such as Quantity Surveyors who use BIM, BIM managers, VR specialists in construction, and Project Managers who work with digital construction technologies. These individuals are best positioned to offer a comprehensive understanding of both the challenges and opportunities involved in integrating VR with BIM for cost estimation, making them ideal candidates for the study. As highlighted in the literature, professionals in these positions can offer valuable technical and strategic insights into the integration of new technologies within the construction industry (Creswell, 1994). By focusing on experts with relevant experience, this research aims to gather detailed responses that contribute to a deeper understanding of the potential and challenges of VR-BIM integration in construction.

Table 1.0 The Sampling Method

<table>
<tr><th>Research Objectives</th><th>Collection Instrument</th><th>Respondents</th><th>Data Analysis</th><th>Research Outcome</th></tr>
<tr><td>To investigate the potential of integrating VR technology in BIM-based cost estimation.</td><td rowspan="2">Semi-structured interview</td><td rowspan="2">- QS that uses BIM
-BIM managers
-VR specialist in construction
-Project Manager involved in digital construction technologies</td><td rowspan="2">Thematic Analysis</td><td>Potential of integrating VR in BIM</td></tr>
<tr><td>To identify the key challenges in integrating VR technology in BIM-based cost estimation.</td><td>Challenges of integrating VR in BIM</td></tr>
</table>

C. Data Analysis

Data analysis in this research involves systematically organizing and interpreting the collected qualitative data to draw meaningful insights aligned with the study's objectives. The chosen methodology for this research is Thematic Analysis, which is well-suited for identifying and understanding patterns within qualitative data. This method allows for flexibility, providing a structured framework to uncover key themes and concepts that address the research questions regarding the integration of Virtual Reality (VR) into Building Information Modelling (BIM)-based cost estimation. Thematic Analysis helps in organizing raw data into meaningful categories through

a coding process, where data segments are systematically categorized, allowing for the identification of broader insights. This approach is particularly effective for exploring diverse perspectives, making it ideal for analyzing complex, multifaceted topics such as VR-BIM integration. NVivo software is utilized throughout the analysis process to aid in coding and organizing data, facilitating a more efficient and systematic approach.

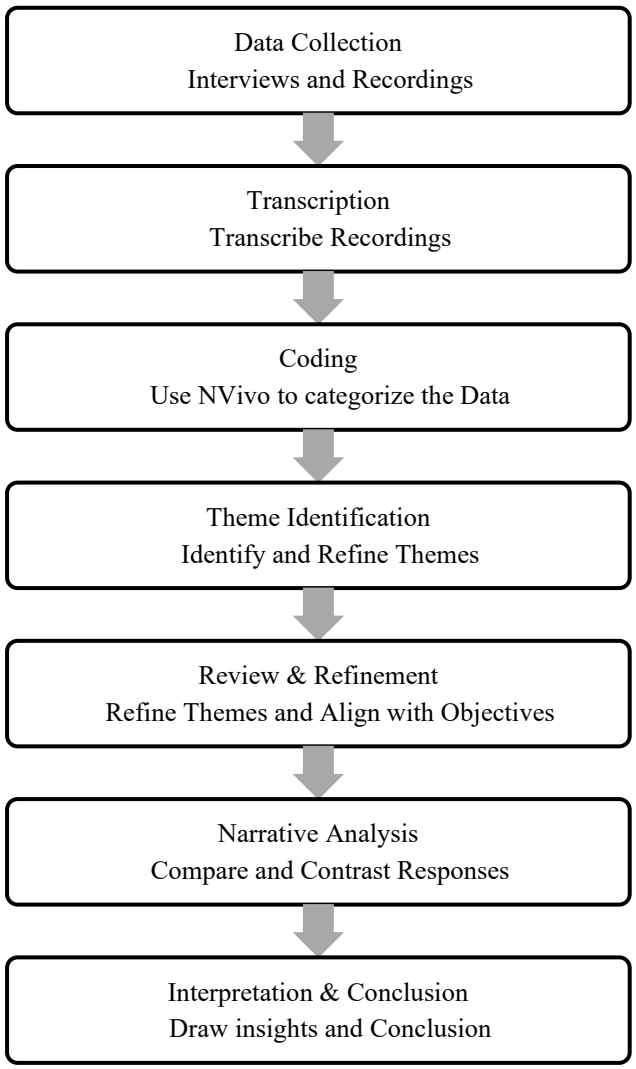


Figure 2.0 Data Analysis Process

The analysis process begins with transcribing the interview data and continues with coding, which forms the foundation for identifying significant themes. NVivo assists in managing and categorizing the data, ensuring a thorough and organized approach to the coding process. Thematic Analysis is followed by an iterative process of theme refinement to ensure that the findings align with the research objectives. Narrative analysis is also employed to compare and contrast various perspectives, identifying connections and unique insights. This comprehensive analysis culminates in a discussion of the findings and recommendations for future research. The final report will present the findings in a structured and organized manner, ensuring clarity and coherence for potential publication.

CONCLUSION

This research explores the integration of Virtual Reality (VR) with Building Information Modelling (BIM) to enhance cost estimation in construction projects. By investigating the potential benefits and challenges, the research aims to improve decision-making, increase cost estimation accuracy, and reduce project delays and cost overruns. The findings contribute valuable insights into how VR can transform traditional BIM-based cost estimation processes, offering practical recommendations for overcoming integration challenges. By addressing both the benefits and challenges of integration, the study provides valuable insights for industry professionals, offering practical recommendations for overcoming barriers such as high costs and technical complexity. Ultimately, this research advances construction project management by demonstrating how the combination of

VR and BIM can lead to more efficient, accurate, and collaborative cost estimation, contributing to the overall improvement of project outcomes in the industry.

ACKNOWLEDGMENT

This research acknowledges the Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia for supporting this research.

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TOWARDS A SECURE AND EFFICIENT CONSTRUCTION PAYMENT SYSTEM WITH BLOCKCHAIN

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ABSTRACT

The construction industry faces persistent challenges such as payment delays, financial disputes, and inefficiencies in contract administration, leading to cost overruns and strained stakeholder relationships. Traditional payment systems involve multiple intermediaries and complex documentation, increasing the risks of fraud, errors, and disputes. As a transformative digital intervention, blockchain technology offers a decentralized and immutable ledger to enhance payment transparency, automate transactions through smart contracts, and secure financial data. This study examines blockchain's feasibility in construction payment systems by evaluating its benefits, challenges, and integration with digital construction technologies. A structured survey of quantity surveyors, contractors, architects, and engineers was conducted to assess blockchain's role in improving payment transparency, reducing delays, and enhancing financial security. Findings indicate that blockchain-based smart contracts automate progress payments, ensuring real-time transactions linked to verified project milestones. Integrating blockchain with Building Information Modelling (BIM) and reality-capture technologies, such as unmanned aerial vehicles (UAVs), enhances project tracking, data security, and automation. These technologies provide authenticated site data, enabling milestone-based payments that reduce human errors and administrative inefficiencies. However, adoption challenges such as high implementation costs, regulatory uncertainties, and industry resistance remain significant. The study highlights that overcoming these barriers through stakeholder education, regulatory improvements, and phased implementation strategies can accelerate blockchain adoption in construction. By leveraging blockchain's digital intervention capabilities, the industry can transition to a transparent, efficient, and dispute-free financial management system, aligning with digital construction technology and Construction Revolution 4.0.

Keywords: Blockchain, Smart Contracts, Construction Payments, Payment Transparency, Progress Payments.

I. INTRODUCTION

The construction industry faces persistent payment challenges, including delays, financial disputes, and contractual inefficiencies, which increase costs and strain stakeholder relationships (Nanayakkara et al., 2021). Blockchain's decentralized, secure ledger enhances transparency, streamlines payments, and reduces dependency on intermediaries (Luo et al., 2019). In 2022, payment issues were a leading cause of adjudication cases in Malaysia, impacting small to mid-sized contractors due to cash flow constraints(Asian International Arbitration Centre (AIAC), 2023). Traditional payment systems involve multiple intermediaries and complex contract administration, leading to higher costs and disputes. Blockchain enables secure, automated payments via smart contracts, reducing delays and disputes (Xianbo Zhao, 2019).

However, blockchain adoption in construction faces challenges such as high implementation costs, lack of standardized frameworks, and integration difficulties. Many firms are unfamiliar with blockchain's mechanics, slowing its acceptance (Das et al., 2020). Additionally, legal and regulatory frameworks for blockchain in construction remain uncertain, creating further hesitation among industry stakeholders (Dakhli et al., 2019). To achieve faster, more transparent, and cost-effective payments, addressing adoption barriers and educating stakeholders is crucial for industry-wide implementation.

The objectives of this research are to identify the perception of construction stakeholders on the potential of blockchain-based payment in construction projects and to identify the perception of construction stakeholders on the challenges for blockchain-based payment in construction projects. This study aims to explore stakeholders' viewpoints on both the opportunities and obstacles associated with implementing blockchain technology in construction payments.

This research examines construction stakeholders' perceptions of blockchain technology in improving payment processes and the challenges of its implementation in the Malaysian construction industry, focusing on contractors, quantity surveyors, architects, and engineers. It analyzes blockchain's potential to enhance transparency, reduce payment delays, and lower transaction costs, while also identifying technological, regulatory, and operational barriers to adoption. Data is collected through surveys from construction professionals across different company sizes and roles, to provide a comprehensive understanding of blockchain integration in construction payments.

This research investigates the potential of blockchain technology to revolutionize payment processes in the construction industry. The findings are expected to help contractors, quantity surveyors, and other stakeholders understand how blockchain can enhance transparency, security, and efficiency in payment transactions. In construction projects, payment delays and disputes often cause cash flow issues, project delays, and strained relationships. This study explores blockchain's ability to optimize payment processes, providing an immutable and decentralized transaction record, reducing fraud risk and strengthening trust among stakeholders.

Additionally, the research examines how blockchain enables faster payments through smart contracts, automating payment triggers upon milestone completion, ensuring timely compensation for contractors and suppliers. It also analyzes blockchain's impact on alleviating cash flow challenges for small and medium-sized contractors. Moreover, the study explores potential cost savings in project management and dispute resolution, minimizing administrative overhead, payment disputes, and processing time. This research contributes to raising awareness of blockchain's transformative role in construction payment systems, supporting its adoption to enhance efficiency, transparency, and collaboration in the industry.

II. LITERATURE REVIEW

a. Payment Provisions in Standard Forms of Contract

Non-payment in construction occurs when contractors do not receive payment for completed work, leading to cash flow issues, project abandonment, and potential insolvency (Badroldin, 2016). Employers may delay payments due to financial difficulties, disputes over work quality, or mismanagement of project funds. Contractors often seek legal remedies such as work suspension, interest claims, or initiating winding-up petitions under the Companies Act 1965. While contracts like PAM 2006 and CIDB 2000 allow for work suspension and interest claims, PWD 203A does not explicitly provide these protections. Addressing non-payment requires stronger contractual enforcement, clearer legal frameworks, and improved financial accountability to protect contractors from financial risks

Delayed payment remains a significant issue in construction, affecting cash flow, project progress, and contractor stability (Mohamad et al., 2018). Employers may delay payments due to financial mismanagement, prolonged certification processes, or disputes over work valuation. Additionally, pay-when-paid clauses further delay payments to subcontractors, increasing financial strain. Contracts like PWD 203A (2010) and PAM 2006 outline payment timelines, but enforcement is inconsistent. Legal mechanisms such as CIPAA adjudication provide avenues for dispute resolution, yet many contractors struggle with lengthy claim processes. To mitigate delayed payments, ensuring compliance with contract terms, timely documentation, and strict financial oversight is crucial.

Underpayment occurs when contractors receive less than the certified amount, impacting cash flow, material procurement, and subcontractor payments (Suhana & Judi, 2020). This issue often arises due to valuation disputes, administrative inefficiencies, and financial constraints of employers. Contractors facing underpayment may experience delayed material supplies, subcontractor withdrawals, and strained industry relationships. While standard contracts attempt to regulate payments, ineffective enforcement and mismanagement continue to cause issues. Preventing underpayment requires clearer valuation processes, standardized payment enforcement, and improved financial transparency to ensure fair compensation for contractors.

The PAM Standard Form of Contract 2018 provides a structured payment framework for private-sector AI(With Quantities), 2018). Clause 30 outlines payment terms, including interim payments, retention funds, and final

account settlements, with payments certified by the Architect based on work progress and compliance with contract terms. Interim Payment Applications (IPA) must be submitted monthly, with the Architect issuing an Interim Certificate within 14 days, followed by employer payment within the Period for Honouring Certificates, typically 30 days (PAM Contract (With Quantities), 2018). Retention sums (5-10%) are withheld, with 50% released at Practical Completion and the balance after the Defects Liability Period (DLP). The system ensures financial stability and minimizes disputes, promoting fairness in construction payments.

The PWD Standard Form of Contract governs public-sector construction projects in Malaysia, providing structured payment schedules and compliance with CIPAA 2012 (Ahmad, 2015). Clause 28 regulates interim payments, requiring contractors to submit monthly payment applications, with the Superintending Officer (S.O.) verifying and issuing an Interim Certificate within 14 days (PWD FORM 203A (Rev. 1/2010), 2010). Clause 31 covers final payments, requiring contractors to submit a Final Account Statement, reviewed by the S.O. before issuing the Final Payment Certificate. Employers must disburse payments within 30 days to ensure cash flow stability, reducing financial disputes (Azman et al., 2014).

The FIDIC Standard Form of Contract ensures fair risk distribution and financial stability in international construction projects, with Clause 14 outlining contract price, interim and final payments, and retention funds (The International Federation of Consulting Engineers (FIDIC), 2017). Contractors submit Interim Payment Applications (IPA) to the Engineer, who issues an Interim Payment Certificate (IPC) within 28 days, followed by employer payment within 56 days to maintain liquidity (KOTB et al., 2017). Retention payments (5-10%) are withheld, with 50% released upon Taking-Over Certificate and the remainder after the Performance Certificate at the end of the Defects Notification Period (DNP) (The International Federation of Consulting Engineers (FIDIC), 2017). The contract also includes advance payments secured by guarantees, ensuring early project funding and cash flow management.

b. Blockchain Technology for Payments in Construction

Blockchain is a decentralized and immutable ledger system that provides secure, transparent, and tamper-proof transactions. It eliminates intermediaries through peer-to-peer transactions, ensuring trust in financial exchanges. Initially developed for cryptocurrencies, blockchain has expanded into various industries, including construction, due to its potential to automate and streamline complex payment systems (Luo et al., 2019). By integrating blockchain, the construction sector can mitigate payment delays, disputes, and inefficiencies in contract administration, reducing reliance on manual processing. This transformative technology enables secure, verifiable digital transactions, enhancing financial stability in construction projects (Das et al., 2020).

Blockchain smart contracts enable real-time, automated milestone-based payments by linking contract terms to verified construction progress, reducing manual approvals and financial disputes. These contracts ensure payment execution upon completion of predefined conditions, enhancing cash flow predictability and minimizing delays (Hamledari & Fischer, 2020). By integrating smart contracts with digital ledgers, payments can be triggered automatically upon project milestone completion, improving efficiency and reducing administrative workload. The combination of blockchain and automation creates a self-executing financial ecosystem, where transactions occur securely without intermediaries (Luo et al., 2019).

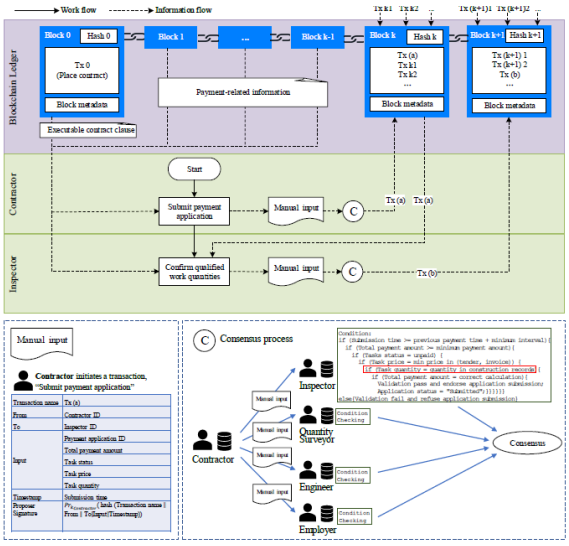


Figure 1.0 Illustration of a blockchain-based smart contract for interim payments (Luo et al., 2019)

Blockchain offers tamper-proof, decentralized payment records, ensuring greater transparency and reducing fraudulent claims. Selective transparency mechanisms provide stakeholders with access to verified financial data while protecting sensitive contract details. This fosters trust among contractors, subcontractors, and suppliers while ensuring a verifiable financial trail (Das et al., 2020). With every transaction recorded on an immutable blockchain ledger, disputes related to mismanaged payments can be significantly reduced. This system strengthens accountability in financial management and eliminates inconsistencies in traditional construction payment methods (Hamledari et al., 2020).

Blockchain enhances cash flow efficiency by reducing payment delays, automating approvals, and eliminating financial intermediaries. The system ensures real-time tracking of payment transactions, reducing disputes over inconsistent documentation and delayed approvals. Furthermore, blockchain provides a secure audit trail, ensuring compliance with financial regulations and facilitating transparent oversight in project finance management. As a result, it minimizes risks related to non-payment or contract breaches, ensuring that contractors and suppliers receive timely compensation (Luo et al., 2019).

Blockchain adoption in construction payments requires substantial investments in infrastructure, software, and skilled professionals, making it financially challenging for small and medium-sized enterprises (SMEs) to implement (Das et al., 2020). Additionally, many construction firms rely on traditional centralized payment systems that lack compatibility with blockchain-based decentralized networks, creating difficulties in integrating the new technology with existing financial and contract management tools (Luo et al., 2019). Without seamless integration, blockchain adoption may disrupt ongoing operations, requiring extensive reconfiguration and retraining of personnel, further increasing costs.

The absence of clear regulations and standardized legal frameworks for blockchain-based payment systems is a significant challenge for its adoption (Hamledari & Fischer, 2020). Many jurisdictions still lack specific laws governing the enforceability of smart contracts, creating legal uncertainty for construction stakeholders who rely on well-defined contractual agreements (Dakhli et al., 2019). Furthermore, in international projects, cross-border blockchain transactions face jurisdictional inconsistencies, making compliance complex and discouraging widespread adoption. Until regulatory bodies establish standardized legal frameworks, stakeholders may remain hesitant to transition from traditional payment mechanisms to blockchain-based solutions.

III. RESEARCH METHODOLOGY

This study employs a quantitative approach using a structured questionnaire to assess stakeholders' perceptions of blockchain-based payment systems in the Malaysian construction industry (Creswell, 2014). The survey allows for the objective evaluation of blockchain's benefits, challenges, and feasibility, providing statistically valid insights into adoption trends. The target population comprises key professionals involved in construction payments, including Quantity Surveyors, Contractors, Engineers, and Architects. Respondents were selected from established bodies such as BQSM, CIDB, LAM, and BEM, ensuring relevance and diversity across project types and company sizes.

As many construction stakeholders may have limited familiarity with blockchain technology, the questionnaire was carefully designed to be accessible and comprehensible to respondents with minimal or no prior exposure. Plain language and non-technical terms were used to ensure clarity and inclusiveness. This approach aligns with the study's objective to assess perceptions across diverse professional backgrounds.

Table 1.0 Research Population

Groups of Respondent	Total Population	Sources
Quantity Surveyor	5,086	Board of Quantity Surveyors Malaysia (BQSM), 2025
Contractor	136,839	Construction Industry Development Board (CIDB), 2025
Architect	2,618	Board of Architects Malaysia (LAM), 2024
Engineer	255,778	Board of Engineers Malaysia (BEM), 2025
Total Population	**400,321**	

Data is gathered through an online questionnaire distributed via professional networks. The survey comprises three sections which are respondents' background, perceptions of blockchain benefits, and challenges to adoption. The questionnaire includes multiple-choice, likert-scale, and open-ended questions, designed to capture industry-wide insights into blockchain-based payment solutions.

Table 2.0 Likert scale of five points

Scale	Indicators	Interpretation
1	Strongly Disagree	1.00 – 2.33 (Low)
2	Disagree	
3	Neutral	2.34 – 3.67 (Medium)
4	Agree	3.68 – 5.00 (High)
5	Strongly Agree	

Table 3.0 Potential of Blockchain-Based Payment in Construction

Category	Code	Statement
Transparency	TR01	Delays and unclear payment status often lead to financial disputes (Luo et al., 2019).
	TR02	Automated recording and real-time updates improve trust and transparency (Dakhli et al., 2019).
	TR03	Securely storing payment records reduces financial disputes (Nanayakkara et al., 2021).
Efficiency	EF01	The current payment approval process is slow due to manual verification (Luo et al., 2019).
	EF02	Automated verification (e.g., BIM, UAVs) speeds up payment approvals (Hamledari & Fischer, 2020).
	EF03	Automating agreements and approvals improves efficiency in processing payments (Das et al., 2020).
Security	SC01	Fraud and unauthorized changes in payment records are risks in construction (Das et al., 2020).
	SC02	Secure systems permanently recording payments protect financial data (Dakhli et al., 2019).
	SC03	Secure storage of payment records prevents unauthorized modifications (Luo et al., 2019).
Risk Reduction	RR01	Payment delays and unclear terms cause financial uncertainty (Das et al., 2020).
	RR02	Automating payment disbursement upon verification reduces delays (Hamledari & Fischer, 2020).
	RR03	Transparent and permanent digital records prevent disputes over unpaid work (Luo et al., 2019).

Table 4.0 Challenges for Blockchain-Based Payment in Construction

Category	Code	Statement
Cost	C01	High setup costs hinder adoption for smaller firms (Das et al., 2020).
	C02	Reducing manual processing fees makes the system cost-effective (Waqar et al., 2024).
	C03	Adoption depends on lowering system setup and operational costs (Kumar Singh et al., 2023).
Integration	I01	Integrating digital payments into contracts (PAM, PWD, FIDIC) requires expertise (Kumar Singh et al., 2023).
	I02	Compatibility issues with traditional financial processes slow adoption (Waqar et al., 2024).
	I03	Standardized guidelines would simplify integration (Luo et al., 2019).
Legal & Regulatory Issues	L01	Unclear regulations create uncertainty in adoption (Das et al., 2020).
	L02	Legal protections and standard contracts encourage adoption (Kumar Singh et al., 2023).
	L03	Government policies and industry regulations are crucial for adoption (Waqar et al., 2024).

User Acceptance	UA01	Resistance to change among construction firms limits adoption (Waqar et al., 2024).
	UA02	Insufficient training on digital payment systems contributes to reluctance (Ariff et al., 2024).
	UA03	Lack of awareness about digital payment applications affects implementation (Nanayakkara et al., 2021).

IV. EXPECTED RESEARCH OUTCOMES

The present research analyzes how construction professionals view payment systems utilizing blockchain technology. Through descriptive statistical analysis, the study systematically examines crucial factors such as deployment costs, workflow optimization, cybersecurity measures, and legal conformity. The analytical framework employs frequency counts, ratio calculations, and mean/median evaluations to comprehensively document varied perspectives across the industry's professional spectrum (Mishra & Alok, 2017). Frequency analysis reveals dominant perspectives, while average scores assess the sector's preparedness for blockchain integration.

While experts recognize blockchain's ability to improve transparency, streamline payments, and minimize conflicts (Hamledari & Fischer, 2020), several barriers impede its adoption. These include high costs, unclear regulations (Luo et al., 2019), a lack of technical knowledge, and reluctance among stakeholders (Nanayakkara et al., 2021). This study employs descriptive analysis to explore these barriers within Malaysia's construction sector, determining whether financial, regulatory, or knowledge gaps pose the greatest obstacles. By systematically presenting stakeholder perceptions, the findings reinforce prior research underscoring the value of descriptive statistics in identifying industry trends before advancing to deeper inferential analysis (Luo et al., 2019).

This research examines the impact of key adoption factors particularly cost, security, and regulatory issues on construction professionals' decisions to implement blockchain-based payment solutions. Using inferential statistics, we extend prior theoretical frameworks (Waqar et al., 2024) to move past basic descriptive findings (Zaid, 2015), enabling deeper analysis of adoption patterns. Through ANOVA analysis of group differences and logistic regression modeling of adoption probabilities, we derive statistically robust insights into blockchain implementation in construction.

Scholarly perspectives differ on the primary barriers to blockchain adoption. While (Hamledari & Fischer, 2020) demonstrate blockchain's potential to accelerate payments through automated reality capture systems, Academic research presents divergent views on blockchain adoption in construction. On one hand, (Luo et al., 2019) demonstrate how the technology's inherent transparency strengthens stakeholder trust and facilitates collaboration. On the other hand, (Waqar et al., 2024) identify substantial implementation costs and unresolved regulatory concerns as persistent obstacles. This dichotomy in scholarly opinion underscores the complex interplay of factors influencing blockchain integration within the sector. By analyzing these relationships within the Malaysian construction sector, this study contributes to the ongoing discourse by determining whether economic barriers or institutional limitations have a more significant influence on adoption rates. This inferential analysis bridges the gap between theoretical advantages and real-world feasibility, providing deeper insights into the industry's readiness for blockchain integration.

CONCLUSION

Blockchain technology presents significant opportunities to revolutionize payment systems in the construction industry through enhanced transactional transparency, reduced conflicts, and improved financial efficiency (Luo et al., 2019). Despite these advantages, the technology's adoption encounters persistent challenges, particularly regarding unclear regulatory frameworks, prohibitive setup expenses, and reluctance from industry participants (Waqar et al., 2024). Addressing these challenges necessitates a multi-faceted strategy involving policy formulation, stakeholder collaboration, and technological integration with existing systems like BIM. Enhanced education about blockchain's operational benefits may also promote greater acceptance within the sector. This investigation examines whether Malaysian construction professionals' perceptions mirror established adoption barriers documented in literature particularly financial considerations, security advantages, and regulatory concerns. Confirming these barriers would substantiate current knowledge about adoption challenges, whereas greater-than-anticipated acceptance may indicate shifting industry perspectives, possibly resulting from educational campaigns. Future studies should focus on applied deployments via pilot projects and real-world implementations to assess blockchain's long-term impact on construction financial systems. Overcoming existing

obstacles could position blockchain technology as a fundamental component of reliable, verifiable, and streamlined payment frameworks within the sector.

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ARTIFICIAL INTELLIGENCE (CHATGPT) IN QUANTITY SURVEYING TASKS – A CONCEPTUAL STUDY

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ABSTRACT

The evolution of Artificial Intelligence (AI) has significantly revolutionized various industries in the world, including construction industry and Quantity Surveying (QS) profession. This study was carried out to analyze the impact of AI, especially ChatGPT, on task applications in the QS profession. The study is conducted to evaluate the potential of ChatGPT in enhancing the traditional method on task application in the QS profession such as cost estimation and planning, quantity measurement and risk analysis in terms of cash flow. A quantitative approach was used by conducting surveys among QS professionals. By having an industry professional point of view, the insights of benefits, challenges, and adoption level of AI can be analyzed better to ensure the outcomes of this research meet the objectives which is to evaluate the adoption of ChatGPT in the QS profession in Malaysia, to identify the benefits and challenges of using ChatGPT in QS profession, and to identify the key applications of ChatGPT in QS tasks. The findings reveal that ChatGPT offers many beneficial impacts to the QS profession, such as precise cost estimation and accuracy and clarity of Bill of Quantities (BoQ) by conducting a detailed data analysis. However, it also comes with few challenges that remain concerning the professionals, such as skills gap and reliability. In short, this research contributes to the better understanding of ChatGPT's role in constructing the future of the QS profession, highlighting the importance of balancing between technological advancements and professional expertise.

Keywords: Artificial Intelligence, ChatGPT, Quantity Surveying, Impacts, Construction Industry

I. INTRODUCTION

The global construction industry is experiencing a transformative shift, driven by the integration of digital and artificial intelligence (AI) technologies aimed at improving project efficiency, accuracy, and decision-making (Mitchell, 2023). Among the various professions impacted by this technological evolution, Quantity Surveyors (QS) play a crucial role in managing construction costs, contractual obligations, and financial planning. Historically, QS professionals relied on manual paper-based methods and basic spreadsheet tools for tasks such as measurement, cost estimation, and documentation. Over time, the introduction of advanced tools like Building Information Modelling (BIM) enhanced these processes, increasing efficiency in measurement accuracy and cost management (Olanrewaju & Abdul-Aziz, 2015).

The next phase of this evolution is the integration of AI-powered tools such as ChatGPT, which offers powerful language processing capabilities to support QS tasks. ChatGPT, a generative AI model developed by OpenAI, enables professionals to process large volumes of data, generate reports, and enhance communication efficiency. It holds particular promise for repetitive task automation, document generation, and decision support in cost estimation and contract administration (Rane, 2023; Rao, 2022). While global leaders such as the United Kingdom and Australia are already leveraging AI tools like ChatGPT for real-time project monitoring, risk management,

and data-driven decision-making (Ng et al., 2024; Deshapriya et al., 2024), Malaysia's construction industry lags in adoption due to technological, infrastructural, and cultural barriers (Mitchell, 2023).

Despite AI's rising potential, the integration of ChatGPT within the Malaysian QS profession remains significantly underexplored. The current research landscape mostly focuses on AI adoption in broader construction contexts, leaving a noticeable gap in literature specific to how tools like ChatGPT influence QS task execution. Critical functions such as cost estimation, procurement, contract administration, and communication which is core to QS roles have yet to be thoroughly investigated through the lens of ChatGPT (Gesikowski, 2023). Furthermore, there is limited empirical evidence evaluating ChatGPT's practical contributions, particularly within Malaysia, where varying levels of digital readiness and awareness persist.

Resistance to AI adoption among experienced QS professionals, driven by unfamiliarity and concerns over data privacy and ethical implications, further complicates implementation (Saini, 2023; Perera et al., 2017). Conversely, younger QS professionals, including recent graduates, are more receptive to AI tools but often lack organizational support and structured training to utilize them effectively. This inconsistency across the profession results in fragmented and inefficient AI integration efforts, impeding the potential benefits that tools like ChatGPT can offer.

This paper addresses a critical research gap by exploring the key applications of ChatGPT in QS tasks, particularly in the Malaysian context, and evaluating the factors that influence its adoption. Hence, this research objectives are to evaluate the adoption of ChatGPT in the quantity surveying profession in Malaysia and identify the benefits and challenges related to ChatGPT. Moreover, this research also aims to identify the key applications of ChatGPT in quantity surveying tasks. By focusing on this underexamined yet significant area, the research offers valuable insights that may influence future QS practices, inform organizational policies on AI integration, and guide future studies in digital transformation within the construction sector. Ultimately, this study aims to contribute to the modernization of the QS profession in Malaysia, promoting greater efficiency, adaptability, and innovation in an increasingly digital construction environment.

II. LITERATURE REVIEW

2.1 Artificial Intelligence in Construction Industry (Quantity Surveying)

Artificial Intelligence (AI) refers to computer systems that can perform tasks typically requiring human intelligence, such as learning, decision-making, and problem-solving (Russell & Norvig, 2021). AI can be grouped into four categories: systems that think like humans, act like humans, think rationally, and act rationally. Additionally, AI is divided into Narrow AI (weak AI) and General AI (strong AI). Narrow AI focuses on specific tasks such as facial recognition, driving, or playing chess, and it is the most common type used in construction. General AI, which can think and act like a human across many situations, is still in development.

In the construction industry, and particularly in the Quantity Surveying (QS) profession, AI is increasingly used to enhance efficiency and support better decision-making. Common applications include cost estimation, project planning, contract management, and risk assessment. Narrow AI tools like algorithms and natural language processing (NLP) systems (e.g., ChatGPT) help quantity surveyors manage large volumes of data, prepare reports, analyze contracts, and communicate more effectively (Zhang et al., 2020; Olatunji et al., 2021). These tools support QS professionals in completing tasks more accurately and efficiently, especially during pre-tender, tender, and post-tender stages.

2.2 Evolution of Artificial Intelligence in the Construction Industry (Quantity Surveying)

The application of AI in construction has experienced multiple stages which demonstrate advancements in both technological digitization and automated processes. The Manual Phase kept traditional Quantity Surveying (QS) practices that depended heavily on paper documentation and manual computations and expert estimates for contract evaluation and cost calculations. The Digital Phase brought Building Information Modeling (BIM) and CostX cost-estimating software along with other computational tools that combined to improve operational efficiency while reducing errors and accelerating calculations according to Kaplan and Haenlein (2019). The present AI Integration Phase enables the use of AI-powered applications with machine learning algorithms to assist QS professionals by performing data-driven analysis such as to forecast project cost and schedule with improve accuracy. Moreover, AI also help to reduce human errors in project assessment by assisting in project documentation and monitoring, and communication between stakeholders especially in Pre-tender stage.

Predictive analytics along with risk management systems based on AI are projected by experts to guide the sustained expansion of AI functions in QS applications for new construction projects. Project data interactions by QS professionals will get transformed through these technological advances leading to better financial plan and contract management efficiency.

2.3 ChatGPT and Its Role in Quantity Surveying

ChatGPT, which stands for *Generative Pre-trained Transformer*, is an artificial intelligence language model developed by OpenAI in 2022. It utilizes natural language processing (NLP) to generate human-like text based on user inputs. Trained using deep learning techniques and transformer neural networks, ChatGPT predicts and constructs text in real-time sentence by sentence and paragraph by paragraph, based on vast amounts of data. This enables it to perform tasks such as composing articles, essays, coding scripts, reports, emails, and even social media posts with remarkable fluency (Brown et al., 2020).

In the construction industry, and specifically in the Quantity Surveying (QS) profession, ChatGPT plays an increasingly relevant role. It supports QS professionals by streamlining project documentation, assisting in cost estimation, and facilitating communication with stakeholders. For example, ChatGPT can generate initial drafts of contract summaries, reports, or meeting notes, reducing the time spent on administrative duties. It also contributes to more accurate forecasting and analysis of project data, minimizing the risk of human error in planning and budgeting tasks. Its ability to process and analyze large datasets enhances decision-making across various stages of a project, particularly in the pre-tender phase where early planning and cost evaluation are critical (Nguyen et al., 2022).

While tools like Google Gemini and Perplexity AI may excel in multimedia processing or real-time search capabilities, ChatGPT distinguishes itself with its powerful language generation and task versatility. For quantity surveyors, this translates to faster reporting, smarter data interpretation, and better overall project communication. Despite being relatively new in the construction sector, ChatGPT's integration has already begun to enhance QS practices by improving documentation, analysis, and collaboration across project teams.

2.4 Functionalities of ChatGPT in Quantity Surveying Profession (Pre-contract and Post contract)

Traditionally, a Quantity Surveyor (QS) plays a central role in managing both the pre-tender (pre-contract) and post-tender (post-contract) stages of a construction project. In the pre-tender stage, QSs are responsible for preparing early cost estimates, conducting feasibility studies, cost planning, preparing tender documents such as Bills of Quantities (BQ), and analyzing contractor bids to help clients make informed decisions (Ashworth et al., 2019; Perera, 2015). In the post-tender stage, QSs manage tasks like progress valuations, cash flow forecasting, final account preparation, handling contract variations, and resolving disputes to ensure financial transparency and cost control (Smith et al., 2011; Ashworth et al., 2019).

With the integration of Artificial Intelligence (AI) technologies like ChatGPT, many of these tasks can now be enhanced or streamlined. In the pre-tender stage, ChatGPT can assist in developing more accurate and data-driven cost estimates by analyzing past project data and current market trends, thus improving budget planning (RICS, 2024). It also helps with quantity takeoffs by interpreting construction drawings and extracting material quantities more quickly than traditional manual methods, reducing errors and saving time (Kreo, 2023). Moreover, ChatGPT can support QSs in preparing well-structured documentation such as cost reports and feasibility studies, improving consistency and communication across teams (Entri, 2024).

In the post-tender stage, ChatGPT enhances cost monitoring by analyzing real-time project data to predict risks, support decision-making, and suggest mitigation strategies, which ultimately leads to better project outcomes (RICS, 2024). Additionally, ChatGPT supports clearer communication among project stakeholders by providing instant insights and making project information more accessible, which improves coordination and issue resolution during construction. While current AI tools still face limitations in handling complex or highly contextual QS tasks, future developments may enable even deeper automation and decision support. By embracing

these technologies, QS professionals can shift more focus toward strategic roles, improve project delivery, and contribute to a more efficient and transparent construction process.

2.5 Traditional QS Methods Vs. ChatGPT-Approach

Traditional Quantity Surveying (QS) methods involve a lot of manual work, such as doing calculations, preparing reports from different sources, and checking contract details to avoid mistakes. Although these methods have worked for many years, they are slow and can lead to human errors (Russell & Norvig, 2021). ChatGPT helps by automating repetitive tasks, which reduces errors and lets QS professionals focus on more important decisions.

Table 1. 0 Literature Review in Comparison Between Traditional Approach and ChatGPT in QS Tasks

Task	Traditional Approach	ChatGPT-Assisted Approach
Cost Estimation	Relies on manual calculations, potential of human error (Ashworth et al., 2019)	Automated data analysis for precise cost estimation (Towey, 2021)
Quantity Takeoff	Time-intensive manual measurement from drawings (Ashworth et al., 2019)	Automated extraction from digital drawings (Towey, 2021)
Documentation & Reporting	Manually drafted report, risk of inconsistency (Ashworth et al., 2019)	AI-generated reports ensure accuracy and clarity (Towey, 2021)
Risk Analysis	Limited due to individual experience and past data (Ashworth et al., 2019)	Predictive analysis based or large data sets (Towey, 2021)

2.6 Benefits and Challenges of ChatGPT in Qs Profession

ChatGPT's integration into the Quantity Surveying (QS) industry boosts productivity by automating tasks like data entry, cost calculations, and report generation. This saves time and allows QS professionals to focus on more strategic and analytical work, speeding up project timelines (Aibinu & Pasco, 2021). Additionally, ChatGPT improves accuracy by reducing human error in complex calculations, leading to better cost estimates and financial reports, which helps manage risks (Olanrewaju et al., 2022).

Another benefit of ChatGPT is cost savings for construction companies. By automating repetitive tasks, organizations can reduce the need for manual labour, cut operating costs, and increase profits (Olanrewaju et al., 2022). ChatGPT also offer valuable insights, helping QS professionals make better decisions about risk, resource allocation, and budgeting, ultimately improving project outcomes (Aibinu & Pasco, 2021).

Despite the benefits, there are challenges when using ChatGPT in QS. One major concern is data security. Sensitive project information could be vulnerable to cyberattacks if not properly protected. To address this, strong cybersecurity measures are essential (Aibinu & Pasco, 2021). Another issue is the potential for job displacement. As AI automates more tasks, certain jobs in technical and administrative areas might be reduced, leading to workforce changes.

Finally, as AI technology evolves, QS professionals will need to learn new skills to use these tools effectively. Upskilling in areas like digital project management, AI, and data analysis is necessary, but some professionals may struggle to keep up with these changes without proper training.

III. METHODOLOGY

3.1 Research Design

This study adopts a quantitative research design, which is effective for collecting measurable data to analyze trends and perceptions (Creswell, 2014). A structured questionnaire is used to gather input from Quantity Surveying (QS) professionals regarding their use and views on Artificial Intelligence (AI), particularly ChatGPT, in daily QS tasks. The survey is divided into four sections. Section A collects demographic and background data such as age, job scope, experience, and familiarity with AI. Section B explores respondents' understanding and usage of ChatGPT across various QS stages which is pre-tender, construction, and post-tender. Section C evaluates perceived benefits and challenges of using ChatGPT, using a 5-point Likert scale and open-ended questions to obtain both quantitative and qualitative feedback. Section D gathers recommendations on future improvements and the integration of AI in QS education and practice. This method allows for broad data collection and statistical analysis while also capturing individual insights (Saunders, Lewis, & Thornhill, 2019).

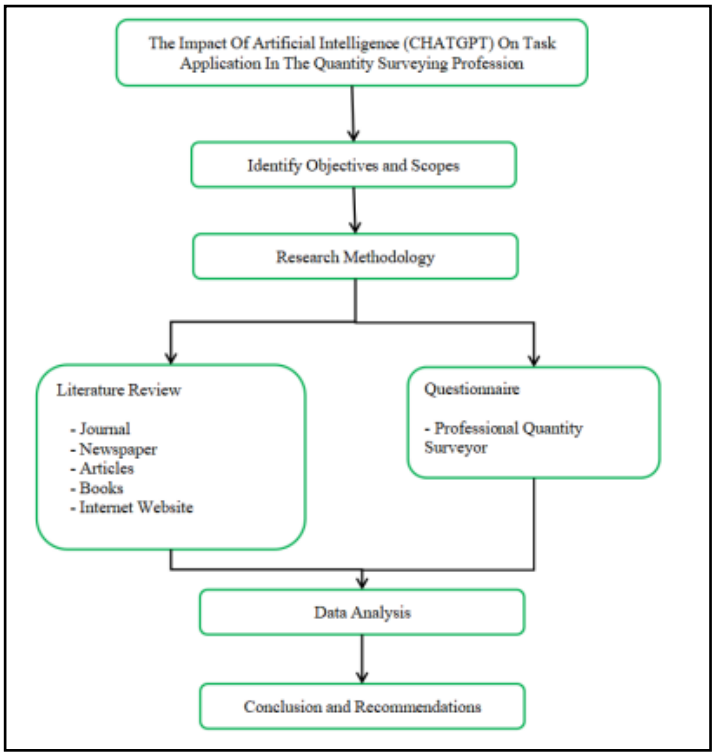


Figure 1.0 Research Process

3.2 Population and Sampling

This research focuses on a quantitative survey targeting Quantity Surveyors (QS) working in government, consultant and contractor organizations within Malaysia's construction industry. According to data from the Board of Quantity Surveyors Malaysia (BQSM) and professional bodies, the estimated population of registered QS

professionals in Malaysia is approximately 4,000 individuals.

To ensure a representative and reliable sample, this study uses stratified random sampling, considering different levels of professional experience and organizational roles. A total of over 100 QS professionals will participate in the survey. Based on Krejcie and Morgan's (1970) sample size determination table, a population of 4,000 requires a minimum sample of approximately 351 to achieve a 95% confidence level with a 5% margin of error. However, as this study is exploratory in nature and constrained by time and access limitations, a sample size of 100 or more respondents is considered sufficient to provide meaningful insights and detect general patterns and perceptions regarding AI (ChatGPT) adoption in the QS profession.

The questionnaire is structured to collect data on respondents' background, understanding of AI tools, perceived benefits and challenges, as well as recommendations for future integration. This approach enables the study to reflect the perspectives of both early adopters and professionals who are more cautious or resistant to technological advancements (Perera et al., 2017).

3.2 Data Collection Methods

According to Naoum (2012), data collection in research typically involves two main approaches which is primary data and secondary data. This study utilized both approaches to obtain comprehensive and reliable information related to the use of Artificial Intelligence (AI), particularly ChatGPT, in the Quantity Surveying (QS) profession. Primary data in this research was gathered through a structured survey questionnaire, which served as the main instrument for collecting first-hand information directly from professional Quantity Surveyors working in the construction industry. As noted by Malhotra (2003), primary data refers to information collected by the researcher specifically for addressing the research problem. The primary advantage of using this method is that the data is directly tailored to the objectives of the study, ensuring completeness and relevance. However, it can also be time-consuming and costly to administer (Malhotra, 2003). In this study, the primary data collection focused on respondents' background, understanding of AI, perceived benefits and challenges of using ChatGPT, and their recommendations for its future use in QS tasks. The questionnaire was designed with both close-ended and open-ended questions to gather both quantitative and qualitative insights.

In addition to primary data, this study also relied on secondary data to support the research framework and to enrich the literature review. Secondary data refers to information that has been previously collected for purposes other than the current research problem (Malhotra, 2003). This data was sourced from academic journals, articles, books, theses, and reputable online sources. The use of secondary data offers several advantages, including ease of access, cost-effectiveness, and the ability to be obtained quickly. It also helps refine the research problem and may provide answers to certain research questions (Malhotra, 2003). However, secondary data may present limitations such as lack of relevance, outdated information, or differences in objectives and data collection methods compared to the current research needs. Despite these limitations, all secondary sources used in this study were carefully selected to ensure credibility and relevance. They provided a solid foundation for understanding the current landscape of AI in QS practice and informed the design of the survey questionnaire.

By combining both primary and secondary data collection methods, this study was able to obtain a well-rounded view of how AI tools like ChatGPT are being integrated into Quantity Surveying, and the opportunities and concerns they present for the profession.

3.4 Data Analysis Technique

The data collected for this study will undergo statistical analysis using SPSS software. Descriptive statistics will be used to summarize the data, providing an overview of the results. Additionally, correlation analysis and regression modelling will be applied to identify significant relationships between the adoption of AI (ChatGPT) and its impact on Quantity Surveying productivity. These techniques help to quantify the strength and direction of relationships between variables (Field, 2013).

For the open-ended survey responses, thematic analysis will be employed to extract qualitative insights. This approach helps to identify common themes and patterns within the responses, providing a deeper understanding of professionals' perspectives on the use of AI in QS tasks (Rao, 2022).

CONCLUSION

Please note that these findings are preliminary assumptions based on the current understanding of ChatGPT adoption in Quantity Surveying (QS). The data collection is still ongoing, and the following insights are expected once the data is analyzed.

The respondents are likely to represent a wide range of age groups, with a balanced distribution between those under 25 and those above 45 years old. We anticipate that professionals with over 5 years of experience will make up a substantial portion of the sample, providing valuable insights into ChatGPT's impact across different career stages. Moreover, respondents are expected to work in a variety of QS roles, with the majority being Consultant Quantity Surveyors, followed by Contractor Quantity Surveyors and developers. Most respondents will likely be moderately familiar with ChatGPT, with a mix of intermediate and advanced users. We expect that many professionals have begun using ChatGPT occasionally or regularly for tasks like cost estimation, risk identification, and cost reporting. The tool's usefulness is anticipated to be viewed positively, especially in terms of saving time and improving efficiency. Moreover, ChatGPT's application is expected to be most frequent in the pre-tender stage, particularly for cost estimation and tender documentation. During the construction stage, its use may extend to managing variations and cost reporting, while post-tender applications might involve preparing final accounts and assisting with dispute resolution.

Respondents are likely to identify several benefits of using ChatGPT in QS tasks. The tool's ability to save time, improve efficiency, and enhance accuracy in data analysis is expected to be rated highly. Respondents may also highlight its usefulness in checking for patterns or errors and its role in improving decision-making, making it a valuable addition to their workflow. While the benefits are clear, some challenges are expected to emerge. Professionals may express concerns about ChatGPT's lack of QS specific context, which could affect the quality of its outputs. Other potential challenges include the risk of over reliance on AI, data security issues, and difficulties integrating AI with existing QS tools. Additionally, some professionals may feel the need for continuous upskilling to keep up with the evolving technology.

There is expected to be a general sense of optimism about the future role of AI in QS. Most respondents are likely to express confidence that ChatGPT can become a valuable tool for future QS practices, especially if it is continuously improved to meet the industry's specific needs. As for improvements, respondents may suggest enhancing the AI's understanding of QS specific contexts and improving its integration with existing software tools. Regarding recommendations for integrating AI into QS education and practice, respondents might advocate for more training and educational initiatives to ensure that future QS professionals are well-equipped to leverage AI in their daily tasks.

In conclusion, ChatGPT presents significant opportunities for enhancing QS task applications, including cost estimation, contract management, and financial forecasting. However, challenges such as data security concerns, professional resistance, and ethical considerations must be addressed (Rao, 2022). This study highlights the overall adoption level of ChatGPT in the quantity surveying profession in Malaysia, the benefits and challenges of using ChatGPT in quantity surveying profession, and lastly the key applications of ChatGPT in quantity surveying tasks.

ACKNOWLEDGMENT

The main author would like to express his gratitude to School of Housing, Building and Planning, Universiti Sains Malaysia., especially the supervisor for funding this publication.

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IMPLEMENTATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN PREPARING BILLS OF QUANTITIES (BoQ)

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ABSTRACT

Accurate cost estimation in construction plays a vital role in ensuring project success. However, traditional approaches to preparing Bills of Quantities (BoQ) tend to be manual, labour-intensive, and susceptible to inaccuracies. Inaccuracies in BoQ preparation, particularly regarding the measurement of earthwork and substructure work, frequently arise from limited visibility, variable soil conditions, and challenges in capturing precise spatial data. The emergence of Geographic Information Systems (GIS) and Building Information Modelling (BIM) presents valuable opportunities for improving and streamlining the preparation of BoQ through the integration of spatial data and three-dimensional modelling. Nonetheless, the possibilities offered by GIS in the development of BoQ especially for earthwork and substructure work, have not been fully investigated. This study seeks to fill the existing gap by exploring the ways in which GIS can enhance both the precision and effectiveness of BoQ preparation, with particular emphasis on earthwork and substructure activities. This research outlines three primary objectives: (i) to identify the challenges of preparing BoQ for earthwork and substructure work, (ii) to examine the specific functionalities of GIS that can assist QS in preparing BoQ for earthwork and substructure work, and (iii) to determine the potential challenges that hinders the implementation of GIS in preparing BoQ for earthwork and substructure work. This research adopts a qualitative methodology, featuring a comprehensive assessment of current literature and semi-structured interviews with industry professionals, including Quantity Surveyors and GIS experts. This paper seeks to advance the creation of a framework for GIS-enhanced BoQ preparation. It provides valuable insights aimed at enhancing the accuracy of cost estimation and promoting digital transformation within the construction sector.

Key words: Geographic Information System (GIS), Bills of Quantities (BoQ), Cost Estimation, BoQ Preparation.

I. INTRODUCTION

Accurate cost estimation is essential for the success of construction projects, as it enables effective resource allocation and reduces financial risks. The BoQ is a critical document in this process, providing a comprehensive breakdown of materials, labour, and cost estimation (Andhyal et al., 2021). Traditional methods for preparing BoQ rely heavily on manual calculations and professional expertise, resulting in inefficiencies, errors, and inconsistencies, particularly in large and complex projects (Rezouki & Rasheed, 2012). The challenges faced can lead to budget overruns, project delays, and contractual disputes, highlighting the need for a more advanced and reliable approach to cost estimation. Recent advancements in digital technology have introduced GIS and BIM as innovative tools capable of significantly improving the preparation of BoQ (Akindele et al., 2025; Bansal, 2007). BIM offers detailed 3D modelling and enables automated quantity take-offs, thus improving the efficiency of the cost estimation process (Ali et al., 2016). GIS improve the analysis of spatial data, enhancing visualization and informing decision-making processes in construction management (Weerasinghe & Jayasooriya, 2018). While both technologies have been applied separately in the construction sector, their combined potential to enhance BoQ preparation remains underexplored

Research demonstrates that integrating GIS and BIM can bridge traditional and digital BoQ methods. This integration could result in automated data collection, enhanced spatial analysis, and greater accuracy in cost estimation (Sheina et al., 2022; Bansal & Pal, 2007). Various challenges, including system compatibility issues, the need for data standardization, and the requirement for specialized technical skills, hinder the broader implementation of these systems (Harmon & Anderson, 2003). Moreover, while GIS has demonstrated its utility in local government revenue mobilization and property management (Oluwadare & Ojo, 2014), its application in the preparation of BoQ remains under-researched. The construction sector in Malaysia faces growing challenges in ensuring the precision of BoQ and adjusting to the complexities inherent in diverse projects. The adoption of BIM has improved the efficiency of BoQ processes (Lu et al., 2018); however, there remains a significant gap in research concerning the integration of GIS, particularly in the context of preparing BoQs informed by spatial data. This research seeks to explore the possibilities of using GIS in the preparation of BoQ especially for earthwork and substructure work. The research objectives are: (i) to identify the challenges of preparing BoQ for earthwork and substructure work, (ii) to examine the specific functionalities of GIS that can assist QS in preparing BoQ for earthwork and substructure work, and (iii) to determine the potential challenges that hinders the implementation of GIS in preparing BoQ for earthwork and substructure work.

II. LITERATURE REVIEW

2.1 Bills of Quantities (BoQ)

A BoQ is a detailed document that specifies the materials, labour, and related costs required for a construction project. This tool is crucial for cost estimation, project management, and procurement, as it enhances clarity, consistency, and financial accountability (Davis & Baccarini, 2004). The BoQ is essential for enhancing cost management, minimizing conflicts, and fostering competitive bidding among contractors (Razali et al., 2016). They are crucial in contractual agreements, serving as a reference throughout the project lifecycle, including tendering, execution, and final delivery (PPRA, 2021). Despite advancements in digital documentation, BoQ remain crucial for projects requiring precise cost management and efficient resource allocation. Their capacity to adapt to modern technologies, such as BIM, enhances their efficiency by integrating architectural components with accurate cost data (Kodikara, Thorpe, & McCaffer, 1993). The standardization of cost estimation and the facilitation of informed decision-making make BoQ a fundamental element in ensuring financial stability and enhancing communication in construction projects.

2.2 Traditional BoQ Preparation

The standard BoQ preparation methods include project familiarization, measurement and quantification, item description, rate analysis and pricing, compilation, and review. These processes include item descriptions, material and labor quantification, project document review, unit price assignment, and final BoQ compilation. Every stage stress key activity and errors, miscommunication, and manual process inefficiencies might occur.

Table 2.0 The Table of Traditional Process in BoQ Preparation

Project Familiarization	Preparing the BoQ requires a thorough examination of project documentation, such as architectural and structural plans. This process is essential for comprehending the client's scope, materials, and specifications. Communication with the design team is crucial for addressing uncertainties and ensuring precise documentation. This process may be prolonged and susceptible to misinterpretation, especially when documents lack clarity or completeness, which can lead to errors and delays in the project timeline (KV et al., 2016).
Measurement and Quantification	This phase identifies necessary materials, labour, and resources via project drawing analysis, organizing work into categories like foundation, superstructure, and finishes. Manual measurements and calculations heighten the potential for discrepancies, especially with varying interpretations of design documents. Changes in project design require manual updates to the BoQ, potentially resulting in inefficiencies and calculation errors. This situation underscores the need for automated quantification methods (Lendo-Siwicka et al., 2019).
Item Description	The BoQ details each item with specific information, such as material type, grade, and measurements, to ensure consistency (Jalam et al., 2018). Precise descriptions are crucial for minimizing misunderstandings among contractors, promoting transparent tendering processes, and preventing disputes. Human error in descriptions, particularly in large projects, can lead to inaccuracies that create uncertainty, impacting bid accuracy and construction execution. The manual nature of this process heightens the risk of inconsistencies.

Rate Analysis and Pricing	Examination of rates and pricing structures. This phase involves assigning unit prices to materials and labour using market data, historical project costs, and supplier quotes (Davis et al., 2009). Precise pricing is crucial for efficient financial planning. Reliance on variable market conditions renders BoQ susceptible to inaccuracies if rates are not regularly updated. Inaccurate pricing may result in cost overruns and operational inefficiencies (Jalam et al., 2018). GIS tools improve real-time cost estimation and reduce pricing errors through automated data collection and risk assessment.
Compilation and Review	The final phase entails compiling all measured, described, and priced elements into a structured document, organized into sections like preliminaries, substructure, and finishes (Lendo-Siwicka et al., 2019). The BoQ is evaluated for completeness and adherence to project specifications. The manual review process is inefficient and prone to human error, which may result in financial and scheduling complications. Errors in later project stages can lead to significant delays, highlighting the necessity for more efficient and automated review processes.

2.3 Innovated BoQ Preparation

BIM-driven BoQ preparation breakthroughs are next. BIM automates cost estimating, a BIM execution plan is needed, and BIM-based BoQs must meet industry standards. Real-time cost estimation and data integration into the BIM model and data quality issues are also examined. BIM adoption requires a large initial investment and ongoing costs, especially for smaller organizations.

Table 3.0 The Table of BIM-Driven BoQ Preparation

BIM-Based Detailed Cost Estimating	BIM facilitates the preparation of BoQ by directly extracting quantities from 3D models, which minimizes human errors and allows for real-time updates (Babatunde et al., 2019). This integration fosters greater efficiency, reduces delays, and promotes enhanced collaboration among the various stakeholders involved in the project. Nonetheless, differences between the quantities produced by BIM and the actual conditions observed on site can result in variations in the BoQ, necessitating extra time for necessary adjustments (Kim et al., 2019).
BIM Execution Plan	A thoughtfully organized BIM execution plan is essential for effectively incorporating BIM into the practice of quantity surveying. This framework defines roles, outlines data management processes, and establishes workflows aimed at improving the accuracy of the BoQ and facilitating communication among stakeholders (Wang et al., 2021). Nonetheless, the adoption of BIM necessitates specific technical expertise and training, which can present challenges for teams that are not well-versed in BIM tools. This lack of familiarity may result in potential delays during the transition period (Růžička et al., 2022).
Real-Time Cost Estimation and Data Integration	BIM facilitates real-time cost estimation by connecting quantity take-offs with cost databases, which empowers project managers to monitor expenses in a dynamic manner (Zima, 2017). This enhances the clarity of financial information and supports more informed decision-making processes. Nonetheless, the dependability of cost estimates is closely tied to the precision of the BIM model, necessitating ongoing updates and rigorous data management to avoid inaccuracies (Soon et al., 2023).
High Initial Investment and Ongoing Cost	Implementing BIM necessitates a significant investment in software, licenses, and staff training, which can pose a financial challenge, particularly for smaller firms (Alhasan et al., 2017). The necessity for ongoing updates and maintenance places additional pressure on project budgets, which in turn restricts the broader adoption of BIM, even though it holds significant potential for long-term cost savings (Alhasan et al., 2017).

2.4 Geographic Information System (GIS)

A GIS is a technology that employs computer systems to manage, analyze, and visualize spatial data, facilitating decision-making across various fields (Maguire, 1991). GIS integrate conventional database management methods with spatial data models, enabling users to effectively store, retrieve, and manipulate geographic information. This system's fundamental features include spatial analysis, data visualization, and pattern recognition, which are crucial for urban planning, environmental management, and resource allocation (Fotheringham & Rogerson, 2013). In construction, GIS plays a crucial role in enhancing project planning and management. They provide significant spatial insights that facilitate more informed decision-making (Martin, 2009). This method allows for the simulation of real-world conditions, enabling construction professionals to analyze site conditions, optimize logistics, and assess environmental constraints efficiently. The integration of multiple layers of geographic data in GIS improves its utility for spatial analysis, leading to more efficient project execution and enhanced resource utilization (Goodchild, 2003).

2.5 Function of GIS

2.5.1 Data Handling

GIS play a crucial role in acquiring, storing, processing, and retrieving spatial data, which is essential for various applications such as urban planning, environmental management, and resource allocation. Cloud-based GIS significantly improves the analysis of large-scale data, facilitating real-time geographic insights that are crucial for effective governance and disaster management (Wang & Jiang, 2021).

2.5.2 Integration

GIS combine various data layers to enhance spatial analysis and inform decision-making processes. The ability to integrate remote sensing, census, and geospatial data facilitates important applications such as addressing climate change and conducting epidemiological studies. Cloud-based GIS improves data-driven governance through the facilitation of real-time monitoring and predictive modelling (Wang & Jiang, 2021).

2.5.3 Spatial Analysis

GIS facilitate the exploration of spatial relationships, the identification of patterns, and the analysis of geographic events, thereby enhancing applications in fields such as epidemiology and regional planning (Martin, 2009). The integration of AI within GIS significantly enhances hazard assessments by utilizing machine learning techniques, thereby improving spatial predictions that are crucial for urban and environmental planning (Huang et al., 2022).

2.5.4 Visualization

The use of GIS visualization tools, such as maps and 3D models, enhances the interpretation of spatial data (Martin, 2009). Applications of augmented reality (AR) and virtual reality (VR) significantly improve public involvement, urban development, and understanding of spatial concepts by allowing users to interactively explore geospatial information (Jo & Hong-Dwyer, 2024).

2.6 Challenges in Implementing the GIS in BoQ Preparation

2.6.1 High Initial Investment Cost

The integration of GIS into the preparation of BoQ necessitates a significant commitment to software acquisition, hardware enhancements, and the training of personnel. The expense associated with shifting from traditional approaches to digital GIS-based systems can be especially burdensome for smaller companies (Dickinson & Calkins, 1988). Furthermore, the continuous costs associated with licensing fees, software updates, and system maintenance can impose a significant financial burden on organizations that operate with constrained resources.

2.6.2 Technical Complexity

The implementation of GIS involves various technical challenges, largely stemming from its inherent complexity and the specialized knowledge needed for spatial data analysis, cost estimation, and 3D mapping (Goodchild, 2000). Numerous organizations face challenges due to a shortage of skilled personnel, and the lack of organized GIS-based quantity take-off methods contributes to inconsistent adoption (Bansal & Pal, 2013). The presence of these complexities can impede the efficiency and accuracy of GIS.

2.6.3 Data Availability and Quality Issues

The accuracy of GIS in the preparation of BoQ is significantly influenced by the availability and reliability of spatial data. Data that is inconsistent, outdated, or incomplete has the potential to undermine the accuracy of cost calculations (Jebamalai et al., 2019). A significant number of legacy records are still maintained in non-digitized formats, which results in a data conversion process that is both slow and susceptible to errors. Moreover, achieving consistency among various data sources necessitates a robust approach to data management, a capability that many organizations currently do not possess.

2.6.4 Resistance to Change

Numerous organizations are hesitant to shift from traditional BoQ preparation methods to GIS, largely due to a lack of familiarity and apprehensions regarding potential disruptions to their workflows (Goodchild, 2000). Employees express concerns about potential job displacement, whereas management exhibits reluctance stemming from the extra time and resources needed for training initiatives. To effectively tackle this resistance, it is essential to implement organized change management strategies, although this may result in additional delays in the adoption process.

III. METHODOLOGY

3.1 Research Methodology Process

The flow of the research process has been summarized below:

1. *Defining the research focus*
   - Investigate the use of GIS in improving BoQ preparation in Malaysia's construction industry.
   - Objectives: Identify challenges in preparing BoQ; Examine the function of GIS; Determine challenges in implementing GIS.
2. *Literature review*
   - Review existing studies on GIS in construction, BoQ preparation and challenges in implementing GIS.
3. *Sampling strategy*
   - Participant: Experts in GIS and QS who knows about BIM.
   - Use purposive and snowball sampling methods to choose respondent.
4. *Data Collection*
   - Conduct qualitative research method.
   - Interview method: semi-structure interview.
5. *Data Analysis*
   - Apply abductive thematic analysis to discover major patterns and themes connected to GIS implementation in BoQ preparation
6. *Conclusion and recommendations*
   - Analyze findings, achieve research objectives, and propose recommendations for further investigation into the implementation of GIS in the preparation of BoQ.

3.2 Population and Sampling Method

IV. Due to the specialized nature of the study, a non-probability purposive sampling technique is employed to select volunteers possessing the requisite knowledge. This study focuses on Quantity Surveyors with the following requirement:

i. *a minimum of five years of industry experience*

ii. *familiarity with BoQ preparation procedures*

iii. *had experience or knowledge with BIM-integrated cost planning tools*

iv. *possess experience or knowledge in the integration of GIS in the preparation of BoQ*

The target responses will consist of five to seven Quantity Surveyors currently working in the construction sector. In addition to purposive sampling, snowball sampling will be utilized to identify additional qualified participants through referrals from initial interviewees. This method ensures that the information collected is relevant and informative for understanding the challenges and opportunities of utilizing GIS within BoQ processes.

3.3 Data Collection

First, a literature review finds, evaluates, and analyzes BoQ preparation GIS research. This strategy improves research by highlighting knowledge gaps and adding fresh insights. GIS's usage in construction, notably BoQ development, and its barriers are examined in this paper. Searching in Scopus, Web of Science, and Google Scholar for "Geographic Information System," "Bills of Quantities," and "Cost Estimation." This assessment investigates GIS's ability to increase BoQ accuracy, time management, and decision-making, as well as its limits and knowledge gaps. The research and GIS-in-BoQ preliminary studies will use a rigorous methodology. Construction sector interviews with quantity surveyors and GIS professionals will supplement literature analysis. Interviews will show how conventional and GIS-based BoQ preparation uses GIS. Understanding GIS integration's merits and downsides from real-life participants requires interviews. Semi-structured interviews include broad and specific issues. This presentation will cover GIS efficacy, problems, and benefits. The data will be evaluated for content to discover how GIS influences BoQ preparation, including time efficiency, accuracy,

decision-making, and adoption hurdles. This qualitative data will show GIS applications and problem-solving solutions, improving literature analysis.

3.4 Development of Questions

To conduct an effective interview, it is crucial to develop questions that ensure a thorough understanding of the interview process. The inquiries are divided into four distinct sections:

1. Section A: Demographic Information.

   This section gathers essential demographic data about the participant, encompassing their roles, work experience, and knowledge about GIS tool. It is crucial to comprehend the participant's background and degree of familiarity with GIS in BoQ preparation to contextualize the responses effectively.

2. Section B: Objective 1 – Challenges in BoQ Preparation for Earthwrok ad Substructure Work.

   This section analyzes the difficulties faced by professionals in preparing Bills of Quantities for earthwork and substructure projects. This study explores the challenges related to quantification and estimation accuracy, along with the methods used to tackle these issues.

3. Section C: Objective 2 – Specific Functions of GIS in Assisting QS in BoQ Preparation

   This section examines how GIS can improve the preparation of BoQ. This study evaluates professionals' awareness and experiences with GIS, emphasizing its functionalities that may enhance the accuracy and efficiency of BoQ, particularly via spatial data analysis and automation.

4. Section D: Objective 3 – Challenges Hindering GIS Implementation in BoQ Preparation

   The purpose of this interview is to explore the challenges that hinder the implementation of GIS in preparing BoQ. This study explores the technological, regulatory, and industry-related challenges that impede the widespread implementation of GIS.

3.5 Data Analysis

This study will validate accuracy and relevance through comprehensive data analysis. Data preparation requires the verbatim transcription of interview responses to prevent data loss and misinterpretation. Post-transcription, the data will be archived in a qualitative data management system to improve analytical efficiency. Subsequent steps include data coding and categorization. An abductive thematic analysis approach will be utilized, enabling the researcher to iteratively navigate between empirical data and theoretical concepts (Tavory & Timmermans, 2012). Analysis and categorization of interview responses will align with study goals while remaining open to unanticipated ideas. Each component will be analyzed to identify trends in BoQ preparation, GIS functionality, and opposition to GIS installation. The codes will be categorized into substructure and earthwork tasks based on research objectives and emerging findings. Organizing similar codes into themes will illustrate the benefits of GIS in BoQ preparation and the associated application challenges. The study will consider variations in perception based on professional and experiential factors. Identifying key themes enhances a mixed-method approach by emphasizing commonly cited advantages or issues (Stefan, 2021). This provides a comprehensive overview of the limitations and advantages of GIS. The results will be compared with previous GIS studies on BoQ preparation (Bleich & Pekkanen, 2013), contributing to the achievement of research objectives and addressing study issues. This study examines the role of GIS in improving BoQ preparation and construction execution.

3.6 Reliability and Validity

Reliability denotes the degree of consistency exhibited by the data collection method. The study will utilize structured and standardized interview protocols to ensure reliability. Conducting a pre-test with a limited participant group will reveal potential challenges, such as interpretation inconsistencies. Internal consistency of the interview items will be evaluated with Cronbach's alpha to ensure they measure the same underlying construct accurately. The reliability of test-retest and inter-observer methods will be assessed by re-administering the survey after a designated time interval to confirm response consistency (Roberts & Priest, 2006). Validity is essential for ensuring that research accurately represents the concepts under investigation. Aligning interview questions with study objectives is essential for enhancing internal validity, while also considering confounding factors like professional experience and GIS proficiency. Construct validity necessitates the alignment of questions with key constructs, such as the utility of GIS in BoQ preparation, to ensure accurate measurement of intended objectives (Sürücü & Maslakci, 2020). Purposive sampling will be employed to select participants with relevant experience in traditional and GIS-based BoQs, thereby enhancing the study's external validity. This method enhances the findings' relevance, supported by comparisons to existing literature (Basham et al., 2009).

CONCLUSION

This research explores the use of GIS in construction BoQ preparation. For earthwork and substructure projects, BoQ preparation is difficult. This study examines how GIS might improve accuracy, efficiency, and decision-making. The literature evaluation reveals GIS adoption gaps and underlines its benefits and drawbacks. This research provides valuable insights on GIS's practical uses using a carefully designed methodology and industry interviews. Integration difficulties are assessed, and solutions are suggested. This study helps explain how GIS technology affects building procedures and suggests ways to improve BoQ preparation and GIS utilization.

ACKNOWLEDGMENT

I would like to extend my appreciation to the School of Housing, Building, and Planning at Universiti Sains Malaysia with a special mention to my supervisor, Sr. Dr. Nur Syaimasyaza. For her unwavering support, encouragement, and essential guidance throughout the duration of this research voyage. The development of this study has been significantly influenced by her knowledge, deliberate input, and ongoing encouragement. I am authentically grateful for her unwavering support and sincerely appreciate her patience during this period.

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A CONCEPTUAL STUDY OF SATELLITE-BASED AUGMENTATION SYSTEM FOR MARINE NAVIGATION

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ABSTRACT

Global positioning system (GPS) is crucial for marine navigation, providing precise location data, enhancing safety, optimizing routes, enabling efficient fleet management, and ensuring compliance with international maritime regulations. GPS signals are prone to various measurements errors such as atmospheric delays, satellite geometry bias and hardware errors. These errors can lead to inaccurate positioning, compromising marine safety and navigation. Differential correction (DGPS) offers satellite positioning improvement as provided by DGPS reference station. However, limitation in communication coverage complicates reliability of DGPS correction. Satellite communication is vital to support DGPS positioning for marine navigation. The aim of this study is to evaluate the effectiveness of Satellite-based augmentation system (SBAS) to support marine navigation. Two objectives are (a) To demonstrate Thuraya SBAS in marine navigation; To assess the performance of Thuraya thuraya SBAS in marine navigation. Study area will be identified, and the nearest accessible CORS will be used to generate DGPS correction. The DGPS correction will be broadcasted using internet communication to the control centre and user will receive the correction via Thuraya satellite communication. Three receivers shall be used whereby one receiver shall receive DGPS correction via Thuraya satellite communication and second receiver shall receive omniStar SBAS correction. Satellite communication based DGPS navigation shall be performed, and the position shall be recorded. The performance of Thuraya SBAS shall be assessed using accuracy assessment and consistency assessment. Accuracy assessment shall be performed by comparing the position from Thuraya SBAS with the position from SBAS OMNISTAR and Single point positioning (SPP). Consistency assessment shall be performed by comparing the difference in position of the receivers. In summary, this study shall demonstrate the effectiveness of Thuraya SBAS in widening DGPS coverage and improving accuracy for marine navigation.

Keywords: Satelite-based, GPS, Marine navigation

I. INTRODUCTION

Marine navigation has changed considerably alongside the advancement of GPS technology. The use of GPS improved accuracy, adaptability, and efficiency across multiple maritime operations. Using an array of modern GPS devices, a multitude of logistical operations such as fleet tracking, route creation, accident avoidance, and harbor services can be conducted with the utmost ease and precision (Razak et al., 2018).

GPS completely changed the face of marine navigation as it enabled the use of real-time positioning which was next to impossible with previous methods like celestial navigation (López & Antón, 2021). Nowadays, a multitude of technologies are used in marine navigation like GPS positioning and Automatic Identification Systems (AIS) to provide maximum safety and efficiency (Specht et al., 2019). Accuracy of positioning is extremely important for marine navigation as certain specific activities heighten the level of expectation. For example, general

navigation and route creation may only need accuracy within meters, however, docking and highly precise movement may require accuracy finer than those of centimeters (Innac et al., 2021; Yazair et al., 2021).

The precision of GPS is used in marine navigation centers around the technique being employed at any given moment. The two most common techniques are Single Point Positioning (SPP) and Differential GPS (DGPS) which have a marked difference in accuracy. DGPS is substantially better than SPP as SPP offers accuracy of up to ±5 meters while DGPS has an accuracy range of ±1 meter (Yazair et al., 2021). The kind of technique used is usually determined by the differences in the parameters of the maritime operation and whether or not the infrastructure is there to support it. For instance, SPP works best for navigation at sea since there is no need for additional infrastructure. On the other hand, DGPS depends on reference stations that are normally set up by survey departments for enhanced accuracy in coastal and port areas (Dymkova, 2022).

The DGPS are crucial for marine navigation. DGPS offers a correction service for a wider area of coverage. This feature is very useful to maritime activities, where operations frequently covered areas like open-seas navigation, costal monitoring and port operations (Alabi et al., 2024). But Still DGPS has limitations because of the available DGPS correction signals. The coverage of DGPS using radio link is also limited to areas with radio coverage. Such areas may be blocked from radio communication by mountainous terrain or urban developments close to the coast. (Yazair et al., 2019) has shown that such obstacles can block the access of DGPS correction signals, thus blocking users in some directions from obtaining accurate navigational data. In order to overcome these limitations, satellite communication via the internet has been implemented to create what is known as SBAS. This system allows the limitations of radio transmission, providing better positioning information for marine navigation. Tracking vessels is equally important for modern marine navigation. Advanced internet technology enables the development of multi component real time positioning and monitoring tracking systems (Khatun et al., 2020).

This system would let maritime operators track the movement of their vessels, recognizing any problems that may arise, ensuring safe travel, and offering the ease of remote observation from land-based stations. Therefore, this study demonstrates an experimental prototype for a vessel tracking system designed for marine navigation, utilizing Thuraya SBAS for navigation. This paper is divided into six sections. The first section provides an introduction to the study, while the second section includes data collection methods used, including the design of the tracking system, and precise navigation testing using Thuraya SBAS. The third section presents the data Processing of the positioning solutions for precise navigation testing. The fourth section discusses the Result and analysis. Finally, the fifth section focuses on Discussion on limitations of SBAS and sixth section concludes the study and provides recommendations for future research and implementation.

II. DATA COLLECTION

Data was collected over a 6 hour period on 7 hour the vessel sailing from Port Klang to Tg.beruas, amassing a total data of 21104 seconds. Technical challenges during the data collection the vessel doesn’t have enough power supply to supply each receiver. The campaign employed two geodetic-grade antennas and three GPS receivers. The first antenna, a 3200LR12 OmniSTAR model, was coupled with a Trimble 4700 receiver to acquire SBAS positioning data. The second antenna, a Hemisphere A31, interfaced with two receivers: a Hemisphere R330 GPS unit for processing DGPS corrections via an internet satellite communication and SPP respectively. Positional data from Thuraya SBAS, omniSTAR and SPP were output in the National Marine Electronics Association 0183 (NMEA 0183) format, a standard protocol widely used in marine and GPS navigation systems. This setup ensured compatibility and precision in data collection and analysis. Figure 1.0 shows the route the vessel will take place.



Figure 1.0 Data collection for 7 hours.

TRACKING SYSTEM DESIGN

The tracking system is made up of three (3) segments, namely control segment, field segment, and monitoring segment. Figure 2.0 illustrates the overall design of the tracking system.

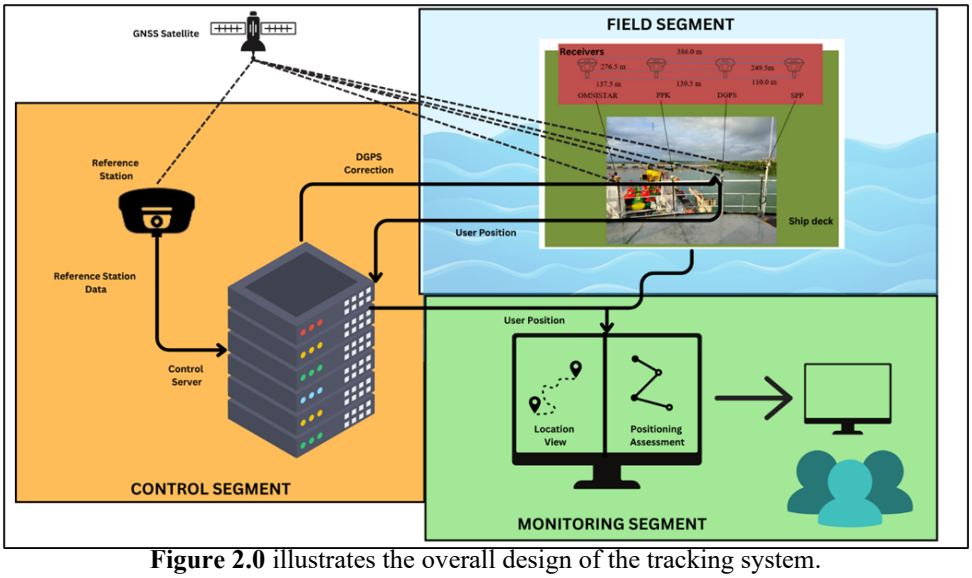


Figure 2.0 illustrates the overall design of the tracking system.

THE CONTROL SEGMENT IN MARINE NAVIGATION SYSTEMS

The control segment is a crucial component of the marine navigation tracking system. It consists of a reference station and a control server. The reference station is a Continuously Operating Reference Station (CORS) established at a location with highly accurate coordinates, using a geodetic-grade GPS receiver. The control server operates using the Networked Transport of RTCM via Internet Protocol (NTRIP), enabling it to receive GPS data and distribute DGPS corrections. In this system, the reference station streams data to the control server, where DGPS corrections are computed. The control server then distributes these corrections via the internet to users and receives their positions in the NMEA 0183 format. Additionally, the control server sends the user's position to the monitoring center for real-time tracking.

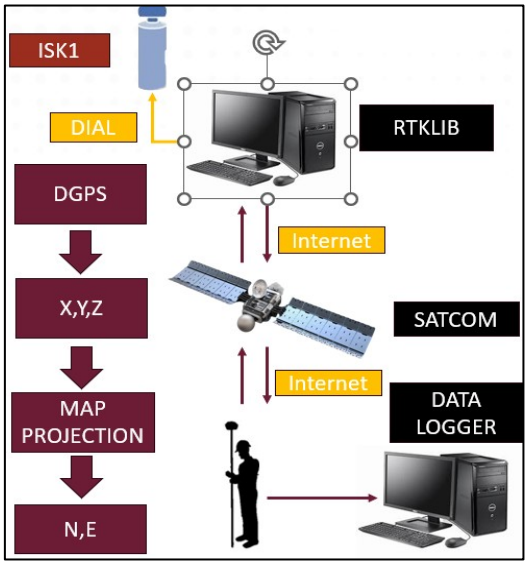


Figure 3.0 detailing communication of data transmitted.

THE VESSEL SEGMENT: EQUIPMENT AND SETUP

The vessel segment includes the ship or boat used for navigation, equipped with GPS receivers and a camera. Two GPS receivers are installed on the vessel at a fixed distance apart. In this study, three receivers are used: whereby one receiver shall receive DGPS correction via Thuraya satellite communication, second receiver shall receive omniSTAR SBAS correction, and third Receiver are SPP. To ensure reliable internet communication, a satellite communication antenna is installed on the vessel. Figure 4.0 show Equipment Setup on Vessel.



Figure 4.0 Demonstrated how GPS receivers are setup on vessel.

THE MONITORING SEGMENT: REAL-TIME TRACKING

The monitoring segment comprises three main components: location view and data logger. The location view is achieved by obtaining the vessel's real-time position from the control server and plotting it on a basemap integrated into RTKLIB, an open-source GPS processing software. Figure 5.0 interface of monitoring segment.

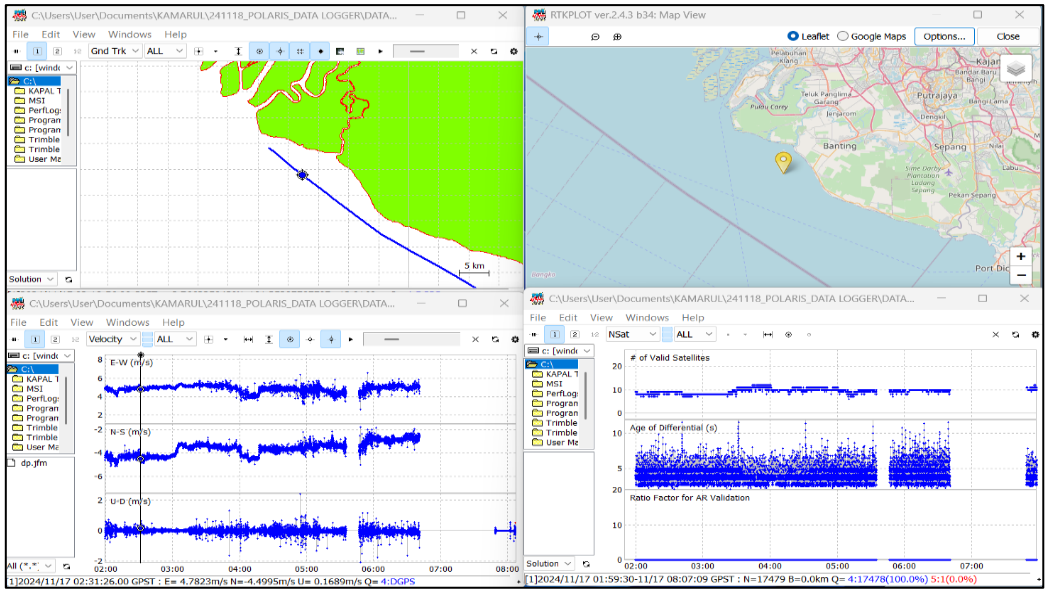


Figure 5.0 The Monitoring Segment: Real-Time Tracking

III. DATA PROCESSING

Raw GPS data were processed using RTKLIB v2.4.3 to compute SPP, often referred to as the navigation solution, relies on code measurements and typically achieves 5–10 meters of accuracy. While other modes of positioning such as Thuraya SBAS and omniSTAR SBAS is received real time during data acquisition. Table 1.0 summarizes each solution involved.

Table 1.0 summarizes positioning techniques, communication and references station.

SOLUTIONS	Positioning technique	Communication	References station
1	Satellite communication SBAS	Satellite communication	ISK1
2	Dedicated SBAS (omniSTAR)	Dedicated satellite communication	-
3	Single Point Positioning	Not applicable	-

All solutions (DGPS, SBAS, SPP, and kinematic) were timestamped in Coordinated Universal Time (UTC) to align with the NMEA-0183 standard. For accuracy comparisons, results were synchronized temporally. Initial coordinates were in the World Geodetic System 1984 (WGS84) datum but projected into Universal Transverse Mercator (UTM) Zone 47N for 2D planar analysis. The positions of the three receivers then compared to the fixed distances.

The 2D positional error ($\varepsilon_2 D$) for each solution was calculated as shown in equation 1.

$$\varepsilon_{2D} = \sqrt{(N_{Solution_1} - N_{Solution_2})2 + (E_{Solution_1} - E_{Solution_2})2} \quad (1)$$

N (northing) E (easting) represents UTM coordinates.

To quantify overall performance, root-mean-square error (RMSE) and standard deviation were computed using:

$$RMSE = \sqrt{\frac{1}{N_i}\sum_{n=1}^{N_i}(\varepsilon 2D)^2} \tag{2}$$

$$Standard\ deviation = \sqrt{\frac{1}{N_i - 1}\sum_{n=1}^{N_i}(\varepsilon 2D - \varepsilon 2D)^2} \tag{3}$$

Where N_i represents number of solutions, and ε2D denotes the mean of 2D error. this study focused on Satellite communication SBAS due of availability and the most cost-effective option for DGPS correction services for navigation.

IV. RESULT AND ANALYSIS

Figure 6 showed the results of the 2D errors for each solution comparison over time. The results showed that satellite communication SBAS has the lowest error, followed by omniSTAR SBAS and navigation solutions. Figure 6.0 shows 2D errors of each solution's comparisons over time.

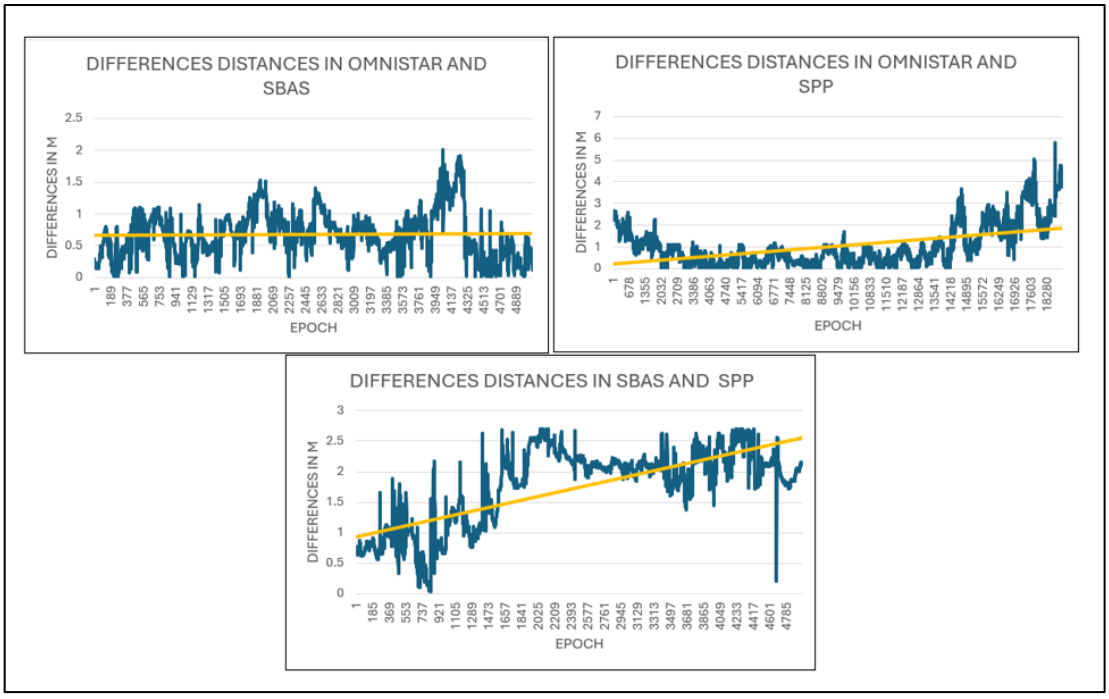


Figure 6.0 2D errors of each solution's comparisons over times.

Table 2.0 demonstrates the performance of these solutions, and it proved that Thuraya SBAS provides better accuracy and precision compared to the navigation solution. Improvement of Thuraya SBAS compared to navigation solution and omniSTAR SBAS are shown in Table 3.0.

Table 2.0 Accuracy and precision assessment

	omniSTAR - SPP	SBAS - SPP	omniStar - SBAS
RMSE (m)	1.046	1.322	0.823
STD.DEV (m)	1.026	0.640	0.372
MIN (m)	0.0001	0.027	0.002
MAX (m)	5.810	1.578	2.005
MEAN (m)	1.094	1.747	0.678

Table 3.0 improvement of SBAS compared against SPP-SBAS and OmniSTAR-SPP.

IMPROVEMENT	SBAS-SPP	OmniSTAR-SPP
ACCURACY	37.72 %	21.32 %
PRECISION	41.85 %	63.70 %

The results show that omniSTAR -SBAS significantly improves both accuracy and precision over SBAS -SPP solution. Specifically, the accuracy is improved by 37.72 %, while the precision shows a 41.85% improvement. This clearly indicates that incorporating differential corrections from SBAS substantially enhances the reliability of the positioning output.

The omniSTAR -SBAS also demonstrates improvements. Compared to omniSTAR -SPP, omniSTAR -SBAS achieved a 21.32% improvement in accuracy and a 63.70 % improvement in precision. It presents a viable enhancement in both accuracy and precision, suggesting that the integration approach can be beneficial under certain operating conditions.

Overall, the results affirm that differential techniques such as SBAS significantly enhance single-point positioning performance. Furthermore, the SBAS provides an additional option for improving positioning quality, though its effectiveness may vary depending on system integration, latency, and real-time data availability. The accuracy and consistency of SBAS was shown to be significantly improved than SPP. It is consistent with earlier studies such as the assessment performed by (Han et al., 2024).

V. DISCUSSION

The findings demonstrate that Thuraya SBAS significantly outperform standard navigation solutions in terms of accuracy. In the following limitations of Thuraya SBAS and omniSTAR SBAS are greatly explained. Some of the studies like (Han et al., 2024) have investigated the applicability of Thuraya SBAS in real-time navigation and found that it is as accurate while increasing its applicability to places with no direct satellite coverage. However, performance may be affected by network instability, leading to diminished reliability in some situations. On the other hand, OmniSTAR SBAS is a subscription-based service requiring specialized receivers. This cost barrier limits its adoption among public users who prioritize affordability over high precision. Apart from that, OmniSTAR SBAS' performance is susceptible to brief signal outages when satellites move out of line-of-sight. For instance, Figure 7.0 shows the outage of the omniSTAR SBAS.

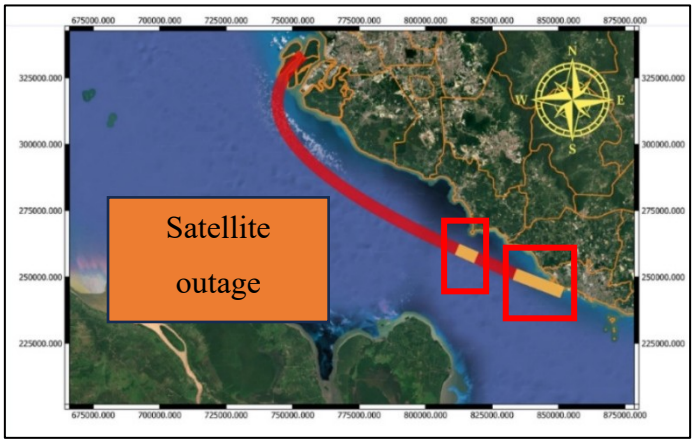


Figure 7.0 omniSTAR satellite outage during observation.

CONCLUSION

The research successfully processed and prepared the data sets required for assessing the performance of Thuraya SBAS in marine navigation. It was shown that Thuraya SBAS could successfully process correction signals and enhance positioning accuracy too. Thus, these findings will be crucial to facilitate robust evaluation of marine navigation technologies. This study is largely a valuable contribution to marine navigation since it has developed a well-organized approach to processing and analyzing GPS data. Furthermore, it exemplifies how Thuraya SBAS can overcome positional inaccuracies often encountered within remote maritime environments. Moreover, this dataset produced would be a rich resource for future comparative studies which would bridge the gap between real-time corrections and high precision. The future studies should expand the area of study to include different marine environments so that these limitations are addressed. Finally, real-time applications of SBAS in highly populated maritime scenarios can be essential when assessing its workability.

ACKNOWLEDGMENT

In preparing this paper, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, PROF. MADYA SR DR. TAJUL ARIFFIN BIN MUSA, for encouragement, guidance, critics and friendship. I am also very thankful to my co-supervisor PROFESSOR DR. WAN ANOM BINTI WAN ARIS, LEE HONG SHENG, PROF. MADYA SR. DR. ABDULLAH HISAM BIN OMAR for their guidance, advice and motivation. Without their continued support and interest, this paper would not have been the same as presented here. I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my assisting my study. Librarians at UTM also deserve special thanks for their assistance in supplying the relevant literature. Finally, I am also grateful for Building Surveying Department of UiTM Perak Branch, for their invaluable guidance and financial support in funding this publication.

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TECHNOLOGY ADOPTION AMONG QUANTITY SURVEYORS IN MALAYSIA

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ABSTRACT

Technology adoption is revolutionizing the construction industry, driving efficiency, accuracy, and collaboration. For quantity surveyors (QSs), digital tools are becoming indispensable in streamlining cost estimation, contract administration, and project management. By leveraging advanced technologies, QSs can enhance decision-making, minimize errors, and optimize resource allocation. However, the rate of technology adoption among QSs in Malaysia remains inconsistent, influenced by various factors. While some professionals actively embrace technology, others face barriers that impede adoption, highlighting the need for a deeper investigation into these barriers and strategies. This study aims to identify the most relevant technologies for QSs, assess their level of adoption, and investigate the barriers and strategies influencing adoption. A quantitative research approach will be employed, using a structured questionnaire to be distributed to QSs in Malaysia. The study is grounded in the Technology Acceptance Model (TAM), which evaluates technology adoption through four key constructs, perceived ease of use (PEOU), perceived usefulness (PU), behavioural intention (BI), and attitude towards use (AU). Additionally, this study aims to uncover barriers that limit adoption and explore strategies to accelerate technology adoption among QSs. The collected data will be analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine the relationships between TAM constructs and to gain deeper insights into the factors influencing QSs' adoption of technology. Additionally, barriers to adoption will be assessed using the Severity Index (SI), while strategies to enhance adoption will be evaluated using the Relative Importance Index (RII). By identifying adoption trends, barriers, and strategic solutions, this study aims to foster a technology-driven QS profession in Malaysia, ensuring that the industry remains competitive in the era of digital transformation. The findings will serve as a foundation for future research, industry reforms, and targeted interventions that drive technology adoption in the quantity surveying profession.

Keywords: Technology adoption, quantity surveyors, quantity surveying

I. INTRODUCTION

The Fourth Industrial Revolution (IR4.0) introduces advanced digital technologies such as Artificial Intelligence (AI), Big Data Analytics, the Internet of Things (IoT), and Building Information Modeling (BIM). These technologies are transforming industries around the world by making work processes faster, more accurate, and more sustainable. In the construction industry, IR4.0 tools help improve project planning, cost management, and communication among teams, offering new ways to tackle challenges (Maskuriy et al., 2019; Zabala-Vargas et al., 2023). Quantity Surveyors (QSs), who are responsible for managing project costs, resource planning, and assessing project feasibility, are in a leading position to benefit from these technologies. Yusof et al. (2022) and Almatari et al. (2024) note that IR4.0 tools allow QSs to streamline workflows, improve accuracy, and contribute to better project outcomes. In Malaysia, the government has been encouraging the use of IR4.0 technologies in construction through Construction 4.0 Strategic Plan 2021-2025 and the Malaysia National 4IR Policy. According Yusoff et al. (2023), these policies aim to modernize the sector by promoting digital transformation to boost productivity, safety, and competitiveness. With IR4.0 adoption, Malaysia's construction industry has the potential to stay competitive in a global market, meeting demands for greater digitalization and efficiency. Despite this push from the government, the actual adoption rate of IR4.0 among QSs remains low due to various challenges, such as high implementation costs, limited access to technology, and skill shortages (Almatari et al., 2024; Saka

& Chan, 2023). Abdul-Samad et al. (2024) and Jaafar et al. (2024) find that similar issues affect other construction professionals as well, pointing to the need for broad support strategies.

To understand how QSs adopt new technologies, researchers often use frameworks like the Technology Acceptance Model (TAM) and the Diffusion of Innovations (DOI) theory. The Technology Acceptance Model, developed by Davis (1989), suggests that how useful and easy-to-use a technology appears influences whether people will adopt it. This model can help explain how QSs view IR4.0 tools, such as whether they believe these tools can make their work more efficient and accurate. Meanwhile, DOI theory by Rogers (2003) looks at factors like compatibility with current work practices and ease of observing benefits, which can influence the adoption speed and success of new technologies. Using TAM and DOI theories in this study can offer a clearer view of the challenges and readiness levels QSs have when adopting IR4.0 in Malaysia. According to Wan Mohammad et al. (2021) and Olawumi & Chan (2019), successfully adopting IR4.0 tools like BIM requires more than just having the technology, it needs an organization that supports change. For example, BIM allows QSs to view projects in detail, access real-time information, and collaborate effectively with team members. However, implementing BIM and other IR4.0 tools requires organizations to promote a culture of change, offer accessible training, and have strong leadership. Without this support, QSs may find it challenging to use these tools to their full potential, even if they recognize their benefits (Saka & Chan, 2023; Yusoff et al., 2023). Furthermore, tools like Big Data Analytics and AI provide QSs with predictive models for cost and data-driven decision-making, which are essential for managing complex projects (Zabala-Vargas et al., 2023).

The rapid advancement of IR4.0 technologies, including Artificial Intelligence (AI), Big Data Analytics, and Building Information Modeling (BIM), presents transformative potential across industries, with particular benefits for the Quantity Surveying (QS) profession. According to Zabala-Vargas et al. (2023), these technologies can greatly enhance efficiency, accuracy, and overall project outcomes by streamlining critical QS tasks such as cost estimation, project planning, and resource allocation, helping QSs meet the demands of a modernized construction sector. Despite these advantages, however, the adoption of IR4.0 technologies among QSs in Malaysia remains notably low, particularly when compared to other areas within the construction sector (Almatari et al., 2024; Saka & Chan, 2023). This limited adoption raises key questions that remain insufficiently addressed in the literature. Shen and Chung (2007) and Smith (2001) emphasize that, although IR4.0 tools can significantly enhance QS workflows, studies specific to QS adoption remain limited, especially in developing regions like Malaysia. Establishing the current level of IR4.0 adoption among QSs is essential to assess their readiness for digital transformation. According to Ibironke et al. (2011) and Musa et al. (2010), such research can clarify how well QSs are integrating IR4.0 tools into their work processes and highlight where significant adoption gaps exist.

To better understand adoption dynamics, this study applies the Technology Acceptance Model (TAM) and the Diffusion of Innovations (DOI) theory as guiding frameworks. TAM, as proposed by Davis (1989), suggests that perceived ease of use and perceived usefulness are significant determinants of users' willingness to adopt new technologies. In the context of QSs, TAM insights could reveal how these professionals perceive the utility of IR4.0 tools in enhancing efficiency and data accuracy. Similarly, Rogers DOI theory (2003) considers factors such as compatibility with existing practices, observability of results, and perceived complexity of technology, all of which play a role in influencing the rate and success of technology adoption. Together, TAM and DOI offer a comprehensive basis for examining the motivations and barriers behind IR4.0 adoption within the Malaysian QS profession. Further, with IR4.0 encompassing a wide array of technologies, identifying those most relevant to QS tasks is essential. Technologies like BIM and Big Data Analytics appear particularly promising, given their potential to support key QS functions. Yet, additional research is needed to clarify which IR4.0 tools offer the greatest benefits and impact within the field, guiding QSs toward tools that best support their specific responsibilities (Yusof et al., 2022; Olawumi & Chan, 2018).

Finally, understanding the factors that influence IR4.0 adoption among QSs in Malaysia is crucial. Key factors may include the financial costs associated with technology, accessibility to digital infrastructure, the availability of relevant training, and the organizational culture's openness to digital change. Tee & Kamal (2021) identify high initial costs of digital tools as a significant barrier, particularly for small and medium-sized QS firms, while Almatari et al. (2024) add that limited financial resources further restrict technology investment. Additionally, Shi et al. (2020) observe that advanced tools like 5D BIM require specialized skills that many QSs currently lack. Furthermore, organizational resistance, often linked to established paper-based workflows, also contributes to the slow adoption of IR4.0 tools (Agyekum et al., 2015; Oyediran & Odusami, 2005). Datti (2017) notes that limited awareness of IR4.0's potential among QSs reduces motivation to adopt these technologies. Addressing these

adoption barriers not only helps explain the limited uptake but also provides practical solutions for fostering a more competitive, resilient QS profession aligned with global IR4.0 trends (Saleh & Ijab, 2023; Yusoff et al., 2023). This research seeks to fill this gap by examining the specific barriers preventing full adoption of IR4.0 technologies among Malaysian QSs. By addressing these under-researched aspects, this study aims to inform policymakers and industry leaders on effective support strategies, including financial assistance, accessible training, and improved infrastructure. Ultimately, the findings from this research will contribute to a stronger, more competitive construction sector in Malaysia, in line with global IR4.0 trends. In short, this study aims to identify the most relevant technologies for QSs, assess their level of adoption, and investigate the barriers and strategies influencing adoption.

II. TECHNOLOGY ADOPTION AMONG QUANTITY SURVEYORS

IR4.0 IN CONSTRUCTION

The Construction Industry Development Board Malaysia (CIDB) implemented the Construction 4.0 Strategic Plan to drive digital transformation across the construction sector. This roadmap aims to boost productivity, improve safety, and enhance sustainability by embedding modern technologies into every stage of construction. It focuses on nine core thrusts, including automation, digitalisation, modern construction methods, and environmental sustainability. One of the key features of the roadmap is its emphasis on the use of advanced technologies. These include: Building Information Modeling (BIM); Artificial Intelligence (AI); Big Data Analytics; Cloud Computing; Augmented Reality (AR) and Virtual Reality (VR). The roadmap also encourages industry players to invest in research and innovation, strengthen their digital capabilities, and continuously upskill their workforce.

IR4.0 TECHNOLOGIES FOR QUANTITY SURVEYORS

Augmented Reality (AR) and Virtual Reality (VR)

According to Ntombela, Tsoeu, and Mhlungu (2024), the implementation of AR and VR is effective for quantity surveyors as AR enables construction elements to be more easily understood, allowing for quantification to be performed more efficiently than when using traditional 2D drawings. VR, on the other hand, provides immersive simulations of real-world environments, reducing the likelihood of on-site injuries while enhancing visualisation of construction sites and buildings without requiring quantity surveyors to be physically present. Nanyam and Makkena (2021) also supported the view that AR and VR are beneficial to quantity surveyors, noting that the use of AR simplifies quantity take-off and enables more precise and efficient workflows. AR allows quantity surveyors to access 3D models for better accuracy in measurement and interpretation.

Cloud Computing

According to Lee (2019), utilising cloud computing facilitates improved communication among relevant parties involved in a project, as construction drawings and other documents can be easily shared with others through an active network connection. Beyond document sharing, cloud computing also functions as a communication platform, enabling real-time updates and helping to centralise project information. This is particularly useful when addressing issues encountered during a project execution, as such matters can be quickly shared among team members for efficient resolution. Furthermore, cloud computing enhances security. As highlighted by Lee (2019), it not only improves accessibility to construction-related documents but also significantly reduces the risk of physical theft. Additionally, it supports disaster recovery by allowing data to be recovered during hardware failures, ensuring documents remain safe and retrievable.

Artificial Intelligence

According to Abioye et al. (2021), AI has significantly contributed to the construction sector by supporting various aspects including resource and waste optimisation, construction site analytics, contract management, supply chain management, project estimation, scheduling, and more. AI-based programmes used in construction projects can also support design alternatives, problem analysis, and solution generation after reviewing current project data (Lee, 2019). By incorporating AI, construction projects can become more efficient, innovative, and cost-effective leading to significant advancements and improvements within the industry. This enables better outcomes through improved planning and execution. AI also plays a crucial role in the early project stages, especially during predesign analysis. It contributes to accurate estimation and informed decision-making related to material selection, cost forecasting, and alternative design strategies (Seidu et al., 2020).

Big Data

For quantity surveying, the implementation of big data can significantly enhance the tender evaluation process. Seidu et al. (2020) highlighted that big data enables more accurate cost comparisons by drawing from historical cost data, preliminary cost analysis, and the establishment of a solid basis for tender evaluation across both past and future projects. As a result, construction cost estimates become more precise and reliable, thereby helping to mitigate the risks of cost overruns and underestimations (Seidu et al., 2020). Furthermore, Maaz et al. (2018) noted that big data also supports improved decision-making. Traditionally, quantity surveyors have relied on their personal intuition or experience when faced with uncertainties. However, these methods can introduce errors in service output. The use of big data eliminates the need for such subjective methods by offering analytical tools that allow quantity surveyors to assess risks and make decisions based on reliable and accurate data.

Building Information Modelling (BIM)

Building Information Modelling (BIM) remains a key focus in advancing the construction industry. The most used in construction are 3D, 4D, and 5D BIM. 5D BIM supports cost estimation by integrating cost-related data into the model, allowing for more accurate forecasting of material consumption and project expenses throughout the lifecycle. By generating a 3D model, BIM enables the extraction of material quantities and properties, which facilitates more accurate planning and estimation (Tahir et al., 2018). According to Quek (2012), BIM adoption by construction practitioners led to numerous benefits: a 40% reduction in budgeted change orders, more accurate cost estimations within the 3% margin of error, an 80% improvement in speed of cost estimate generation, 10% savings in project cost through clash detection before construction, and a 7% reduction in project duration due to fewer delays.

BARRIERS AND DRIVERS OF TECHNOLOGY ADOPTION

Table 1.0 Barriers of Technology Adoption

No	Barriers	Sources
1	Legal and contractual uncertainties	Stanley and Thurnell (2014), Maiskury et al. (2019)
2	Significant expenses associated with the installation of digital equipment and systems	Nnaji et al. (2020), Hong et al. (2016), Reddy (2018)
3	Insecure data security	Nnaji et al. (2020)
4	Insufficient availability of personnel for software support	Hong et al. (2016), Reddy (2018)
5	Lack of expertise	Hong et al. (2016), Reddy (2018), Nnaji et al. (2020)
6	High training expenses	Almatari et al. (2024), Stanley & Thurnell (2014)
7	Reluctance to embrace changes	Reddy (2018), Hong et al. (2016), Almatari et al. (2024)
8	Lack of standards	Seidu et al. (2020), Rokooei (2014)
9	Software incompatibility and interoperability issues	Stanley & Thurnell (2014), Reddy (2018), Musarat et al. (2024)
10	Fragmentation	Maiskury et al. (2019), Stanley and Thurnell (2014)
11	Lack of awareness	Wang et al. (2022)
12	Preference of traditional and current working methods	Wang et al. (2022)

Table 2.0 Drivers of Technology Adoption

No	Drivers	References
1	Competitiveness	Lee et al. (2022), Cater et al. (2021)
2	Demand for excellence and efficiency	Lee et al. (2022), Cater et al. (2021)
3	Requirement by customers	Lee et al. (2022), Cater et al. (2021)
4	Technological advancement and digitization	Lee et al. (2022), Saleh, Ijab & Hashim (2022)
5	Government policies	Pruskova (2019), Saleh, Ijab & Hashim (2022), Mitera-Kielbasa and Zima (2023), Yap et al. (2023)
6	Organizational factors	Saleh, Ijab and Hashim (2022), Cater et al. (2021)
7	Financial support	Akinshipe et al. (2022), Van der Heijden (2024)
8	Shifting top management negative views on digitalization	Vararean-Cochişa and Crisan (2025), Sawhney and Knight (2023)
9	Include practical training of the related technologies	Babatunde et al. (2020), Saleh, Ijab and Hashim (2022), Shuhaimi et al. (2022), Oke et al. (2018)
10	Firms are to provide technology and software training	Ying et al. (2022), Oke et al. (2018)

The adoption of digital technologies is often influenced by a range of potential barriers. These include legal and contractual uncertainties, high costs related to installing digital systems, and concerns over data security. Internally, challenges such as limited software support, lack of expertise, and high training expenses may also

arise. Additional issues include reluctance to embrace change, absence of industry-wide standards, software incompatibility, fragmentation, lack of awareness, preference for traditional methods, and fear of over-investment. While these barriers have been widely discussed in existing literature, they must be further investigated to determine their actual relevance and impact in the context of quantity surveying practice. Conversely, several key drivers have been identified that could encourage the adoption of digital technologies. These include competitiveness, demand for improved performance, customer expectations, technological advancements, and supportive government policies. Organisational readiness, financial support, leadership commitment, and integration of digital training in education and professional development also play important roles. For quantity surveyors in Malaysia, these barriers and drivers will be examined more closely to determine which are most severe and which serve as the strongest motivators. The findings will help guide targeted strategies to support digital transformation within the profession.

III. RESEARCH METHODOLOGY

This study will employ a quantitative research design using a structured survey questionnaire as the primary data collection instrument. The development of the questionnaire is based on two theoretical frameworks: the Technology Acceptance Model (TAM) by Davis (1989), and the Diffusion of Innovation (DOI) theory by Rogers (2003). TAM will be used to examine constructs such as Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Social Influence (SI), which are expected to influence the behavioural intention of quantity surveyors to adopt IR4.0 technologies.

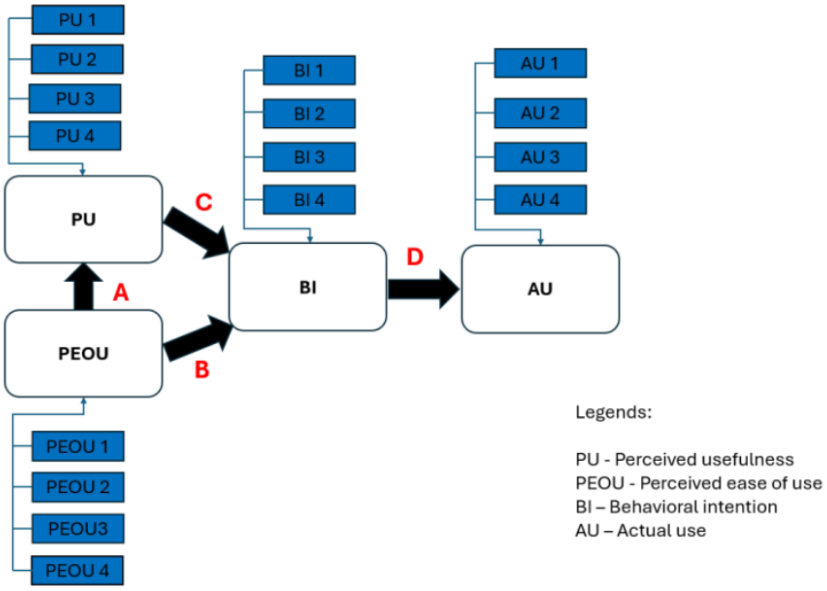


Figure 1.0 TAM model modified from Davis (1989)

As part of the application of Diffusion of Innovation (DOI) theory (Rogers, 2003), this study will also categorise respondents into five adopter groups: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. These categories represent varying levels of openness to adopting new technologies.

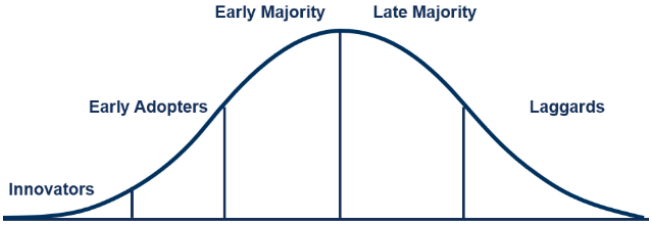


Figure 2.0 DOI model adopted from Rogers (2003)

The questionnaire will consist of sections covering demographic information, awareness and use of IR4.0 technologies, perceived barriers and drivers, and acceptance-related factors. The study will distribute 330 questionnaires to targeted respondents using a purposive sampling technique, focusing on quantity surveying

professionals from both the consulting and contracting sectors, including those from public and private organisations. This sampling strategy is chosen to ensure that responses are gathered from individuals with relevant professional experience and familiarity with technology use in the Malaysian construction industry (Sekaran, 2016). The sample size of 330 is determined based on the Krejcie and Morgan (1970) sample size table for a known population, and is aligned with the current number of registered Quantity Surveyors in Malaysia as listed by Board of Quantity Surveyors Malaysia.

The data collected will be analysed using a combination of techniques. Descriptive statistics will first be used to profile respondents and evaluate the level of awareness and current usage of IR4.0 technologies. To identify and prioritise the most significant barriers and drivers, the Severity Index (SI) and Relative Importance Index (RII) method will be applied to the responses. oth indices are widely used in construction-related research to prioritise factors based on respondent ratings. The SI will measure the degree of seriousness or impact associated with each factor, while the RII will assess their relative importance. Each factor will be rated on a Likert scale, and the indices will be computed using standard formulas:

> **SI = (Σ(W × F)) / (A × N)**, where *W* is the weight assigned to each response, *F* is the frequency of each rating, *A* is the highest weight, and *N* is the total number of responses.
>
> **RII = ΣW / (A × N)**, with similar notation.

These calculations will enable the ranking of factors in order of perceived severity and importance, providing a clear picture of the key enablers and challenges from the perspective of practitioners (Holt, 2014). To assess the relationships between the theoretical constructs and behavioural intention to adopt IR4.0 technologies, the study will employ Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS software. This analytical method is suitable due to its flexibility in handling complex models, smaller sample sizes, and data that may not be normally distributed (Hair et al., 2014). PLS-SEM will be used to evaluate both the measurement model (reliability and validity of constructs) and the structural model (hypothesis testing and path analysis). The use of PLS-SEM is intended to validate the conceptual framework built on TAM and DOI, providing insights into which factors most strongly influence the intention to adopt IR4.0 technologies among quantity surveyors in Malaysia.

IV. EXPECTED FINDINGS

The expected findings of this study will provide valuable insights into the current state of technology adoption within the quantity surveying profession in Malaysia. It is anticipated that the research will identify a core set of IR4.0 technologies that are most relevant to quantity surveyors. The study also expects to reveal varying levels of technology adoption among professionals, influenced by organisational roles, years of experience, and sector (public or private). Through the application of the Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI) theory, the research will likely establish which behavioural and innovation-related factors significantly impact the intention to adopt these technologies. Additionally, the analysis will help rank the most pressing barriers and the most effective drivers or strategies using the SI and RII. It is also expected that respondents will be distributed across the five DOI adopter categories ranging from innovators to laggards allowing the study to assess adoption behaviour by group. Ultimately, the findings will support the development of targeted strategies and policy recommendations to accelerate the adoption of IR4.0 technologies within the quantity surveying profession in Malaysia.

CONCLUSION

This research sets out to explore the readiness and responsiveness of the quantity surveying profession in Malaysia towards the adoption of Industry 4.0 technologies. In doing so, it recognises the growing importance of digital transformation in shaping the future of construction and built environment professions. By adopting a structured, theory-informed, and data-driven approach, the study seeks to contribute to a clearer understanding of how quantity surveyors perceive and engage with technological change. Beyond identifying specific barriers and enablers, this research is intended to offer practical insights that can support policy formulation, educational initiatives, and organisational planning. As the construction industry moves towards greater automation, data integration, and digital collaboration, it is imperative that professions like quantity surveying are equipped with the knowledge, tools, and strategies to adapt and evolve. This study aspires to be part of that effort by laying the groundwork for a more innovative, technology-embracing quantity surveying landscape in Malaysia.

ACKNOWLEDGMENT

The main author would like to express his gratitude to School of the Built Environment, University of Reading Malaysia, especially the supervisor for funding this publication.

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eISBN 978-629-94789-1-1



(online)