



**POTENTIAL APPLICATION OF VIRTUAL REALITY WITH BUILDING
INFORMATION MODELLING IN ADDRESSING ON-SITE PROBLEMS IN
CONSTRUCTION INDUSTRY IN MALAYSIA**

By

NASRIN SYAHIRAH BINTI ZAINUDDIN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
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Master of Science**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfilment of the requirement for the degree of Master of Science

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The construction sector in Malaysia has been coping with a variety of continuous issues that have been occurring on the project site including communication inefficiencies, cost overruns, time delays, and safety concerns. The construction industry is encountering significant problems, but these obstacles can be surmounted by adopting technologies such as Building Information Modelling (BIM) and Virtual Reality (VR). Combining Virtual Reality with Building Information Modelling has been proposed as a possible remedy for many construction challenges. However, there needs to be more comprehension regarding incorporating these technologies, resulting in a sluggish advancement of its acceptability. This research investigates the potential of integrating VR and BIM in addressing key challenges in the construction industry, particularly in enhancing communication, reducing time and cost overruns, and improving safety management. The research focuses

on Grade 7 construction companies in Klang Valley area of Malaysia, as these contractors possess the financial capacity to adopt advanced technologies. The study employs a combination of literature review, surveys, and data analysis to assess the barriers to adoption and the perceived benefits of VR-BIM integration in construction projects. The analyses were conducted using the parameters and data gathered from the survey which were categorised into four constructs, which are Overrun Problems (OP), Overrun Effects, (OE), Management Problems (MP), and Control Measures (CM). The Kendall's tau-b and Spearman's rho tests were employed to analyse the correlation between the constructs. These analyses aimed to ascertain the level of correlation between the constructs to assess the feasibility of implementing these technologies in construction projects. Based on the analyses, the highest correlation is between CM and OE which indicates that effective control measures substantially reduce or mitigate the adverse impacts of overruns. This study is concluded by proposing a framework for integrating VR with BIM to streamline communication, project planning, and risk management within the construction industry. A small group of individuals validated the framework with a background of civil engineering, consisting construction professionals. By addressing these construction site challenges, the construction industry in Malaysia can enhance its efficiency, reduce operational risks, and achieve greater project outcomes. The findings contribute to both academic discourse and practical applications, offering insights into how VR and BIM can revolutionise the Malaysian construction sector.

Keywords: Building Information Modelling, Construction Industry, Construction Issues, Construction Site, Virtual Reality

SDG: GOAL 8: Decent Work and Economic Growth and GOAL 9: Industry, Innovation, and Infrastructure



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**POTENSI APLIKASI REALITI MAYA DENGAN PEMODELAN MAKLUMAT
BANGUNAN DALAM MENANGANI MASALAH DI TAPAK PEMBINAAN
DALAM INDUSTRI PEMBINAAN DI MALAYSIA**

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Industri pembinaan di Malaysia tidak lagi asing dengan pelbagai isu berterus yang berlaku di tapak pembinaan seperti ketidakcekapan komunikasi, lebihan kos, kelewatan masa, dan kebimbangan keselamatan. Industri pembinaan Malaysia berhadapan dengan masalah yang besar, tetapi masalah yang dihadapi ini boleh ditangani dengan menggunakan pakai teknologi-teknologi baru seperti Pemodelan Maklumat Pembinaan (BIM) dan Realiti Maya (VR). Penggabungan teknologi Realiti Maya dan Pemodelan Maklumat Pembinaan telah dicadangkan sebagai salah satu penyelesaian bagi menangani isu-isu di tapak pembinaan. Namun begitu, pemahaman dan pengetahuan yang tinggi adalah diperlukan untuk mengadaptasi teknologi-teknologi moden ini yang menyebabkan kesukaran untuk menerima teknologi tersebut. Kajian ini bertujuan untuk mengkaji potensi penggabungan VR dan BIM dalam menangani masalah utama dalam industri pembinaan, supaya dapat

meningkatkan komunikasi, mengurangkan lebih kos dan masa, serta memperbaiki pengurusan keselamatan di tapak projek. Kajian ini bertumpu pada syarikat pembinaan Gred 7 di kawasan Lembah Klang, Malaysia, kerana kontraktor Gred 7 mempunyai keupayaan kewangan untuk menggunakan pakai teknologi canggih di tapak projek. Kajian ini menggunakan gabungan ulasan literatur, tinjauan, dan analisis data untuk menilai halangan penerimaan serta faedah yang dapat dilihat daripada integrasi VR-BIM dalam projek pembinaan. Analisis dijalankan dengan menggunakan parameter dan data yang diperoleh daripada tinjauan yang dikategorikan kepada empat konstruk iaitu, *Management Problems* (MP), *Overrun Problems* (OP), *Overrun Effects* (OE), dan *Control Measures* (CM). Analisis Kendall's tau-b dan Spearman's rho dilakukan bertujuan untuk memastikan tahap korelasi antara konstruk untuk menilai kebolehlaksanaan melaksanakan teknologi ini dalam projek pembinaan. Berdasarkan analisis, korelasi tertinggi adalah antara CM dan OE yang menunjukkan bahawa langkah kawalan yang berkesan dapat mengurangkan atau menangani kesan buruk lebih kos dan masa di tapak projek. Kajian ini disimpulkan dengan mencadangkan satu rangka kerja untuk mengintegrasikan VR dengan BIM bagi memantapkan komunikasi, perancangan projek, dan pengurusan risiko dalam industry pembinaan. Sebuah kumpulan kecil yang terdiri daripada professional pembinaan dengan latar belakang kejuruteraan awam telah mengesahkan rangka kerja yang dicadangkan. Jika cabaran di tapak pembinaan dapat ditangani, industri pembinaan di Malaysia dapat meningkatkan kecekapan, mengurangkan risiko operasi, dan mencapai hasil projek yang lebih baik. Penemuan kajian ini dapat menyumbang kepada wacana akademik dan juga aplikasi praktikal,

memberikan pandangan tentang bagaimana VR dan BIM boleh merevolusikan sektor pembinaan di Malaysia.

Kata Kunci: Industri Pembinaan, Isu Pembinaan, Pemodelan Maklumat Bangunan, Realiti Maya, Sektor Pembinaan

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LIST OF ABBREVIATIONS

VR	Virtual Reality
CITP	Construction Industry Transformation Program
BIM	Building Information Modelling
AEC	Architecture, Engineering, and Construction
G7	Grade 7
CIDB	Construction Industry Development Board
3D	Three-Dimensional
4D	Four-Dimensional
7D	Seven-Dimensional
AR	Augmented Reality
CAE	Computer-Aided Engineering
HMDs	Head Mounted Displays
PWD	Public Works Department
ROI	Return on Investment
ECE	Engineering Cost Estimating
URL	Uniform Resource Locator
AUC	Receiver Opening Characteristic Curve
ERP	Enterprise Resource Planning
IFC	Industry Foundation Classes
IoT	Internet of Things
OE	Overrun Effects
OP	Overrun Problems
CM	Control Measures
MP	Management Problems

CHAPTER 1

INTRODUCTION

1.1 Background of The Study

The construction sector plays a crucial role in the economic progress of nations worldwide. Like other developing nations, Malaysia is often distinguished by its expanding building industry. The present construction sector in Malaysia is defined by enhanced levels of efficiency, productivity, and technological progress. Lachimpadi et al. (2012) found that the construction sector faces the task of producing substantial quantities of waste in terms of time, money, energy, and materials as a result of the growing need for construction developments and large-scale infrastructure projects. Nevertheless, Olanrewaju (2017) asserts that the primary cause of construction disagreements and issues is the failure or insufficient communication among team members.

The utilisation of Virtual Reality (VR) technology facilitates greater visualisation, hence fostering improved communication among many stakeholders in the construction industry by promoting a holistic comprehension of the project as a unified organism. The integration of VR in Malaysia's construction sector remains nascent, although there is an increasing interest in utilising this technology to enhance project results. The

low acceptance and implementation of VR technology in the Malaysian construction sector can be attributed to a lack of fundamental understanding and experience among construction employees, despite the potential advantages of integrating VR in construction.

Given these benefits, the implementation of VR technologies in Malaysia's construction sector is constrained. Research indicates that although certain companies have initiated the use of VR for training and hazard identification, widespread adoption is impeded by various factors, including higher costs, a deficiency in technical expertise, and inadequate awareness of the technology's advantages (Ghobadi & Sepasgozar, 2020; Ozcan-Deniz 2019). Chen et al. (2022) reported that merely 37% of large construction firms in Malaysia has experience with virtual reality, with only 2.9% fully incorporating technology into their projects. Additionally, the Malaysian government has launched initiatives like the Construction Industry Transformation Program (CITP) to promote the utilisation of novel technologies, including VR and BIM (Wong et al., 2020; Rashidi et al., 2022). The efficacy of these activities mostly hinges on overcoming current obstacles, including the necessity for extensive training and the establishment of a conducive regulatory framework (Adnan et al., 2020).

Wang (2021) states that the use of BIM with VR technology offers distinct advantages in terms of virtual visualisation, information interaction, and management coordination. The capabilities provide the anticipation and flexible regulation of potential variables in the construction process, thereby

bringing a novel approach to the administration of construction projects. According to Heinonen et al. (2022), the progress of VR and BIM technology can enhance communication and efficiency in the Architecture, Engineering, and Construction (AEC) business (Sampaio, 2018).

Incorporating VR into the BIM solution can effectively tackle issues about the retrieval and presentation of information. Moreover, it can potentially enhance the efficacy of communication and problem-solving in a collaborative and dynamic environment. Integrating VR experiences based on BIM can provide benefits. Nevertheless, this undertaking presents challenges since it necessitates advanced technology and comprehensive staff education (Wu et al., 2020).

The growing adoption of BIM in Malaysia indicates that many industry participants understand BIM comprehensively. Nevertheless, most persons in the industry have only a surface-level comprehension of BIM and need to gain the essential proficiency to efficiently employ and modify it, especially in the private sector. In their study, Lee et al. (2022) discovered a direct correlation between BIM-VR technology's perceived usefulness and simplicity and its advantages. The study indicates that users are likely to adopt the new advancements this technology facilitates readily. The widespread deployment of BIM-VR technology will necessitate a substantial amount of time due to the growing prevalence of BIM expertise. However, it is justifiable to claim that the present generation of industry participants is comfortable with the changes and would quickly adopt such technology despite the associated challenges.

1.2 Research Gap

There is a study gap in the construction sector in Malaysia regarding the challenges caused by the lack of knowledge and awareness among construction workers concerning the potential integration of BIM and VR technology. Although the benefits of integrating BIM and VR in solving challenges like cost and time overruns, communication challenges, and safety issues on construction sites are apparent, the slow pace of BIM adoption prevents these advantages from being effectively implemented.

Although the potential of BIM and VR to bring about significant changes is recognised in studies, there is a lack of studies that particularly examine the reasons behind the slow adoption of these technologies in the Malaysian construction industry. The limited knowledge and comprehension among construction workers provide a significant barrier to the smooth adoption of BIM and VR. The lack of complete understanding of the underlying causes of this knowledge gap and the unique difficulties construction workers encountered in adopting these modern technologies highlight the need for more research.

Gaining a comprehensive understanding of how knowledge is spread, identifying the training requirements, and recognising the obstacles encountered by construction workers are crucial in developing successful approaches to expedite the implementation of BIM and, as a result, VR. It is crucial to address this research gap to close the existing imbalance between

the potential advantages of technology integration and the practical obstacles preventing its broad use in the Malaysian construction sector. Addressing this disparity will not only enhance academic progress but also enable the implementation of focused interventions and policies to cultivate a more technologically skilled workforce in the construction industry in Malaysia.

1.3 Problem Statement

Despite the substantial growth, the construction industry in Malaysia has numerous problems that hinder its efficiency and effectiveness. Ghule (2020) has reaffirmed a statement by Aziz and Hafez (2013) which emphasised that these problems include time delays and cost overruns, demanding immediate identification and solutions. In contrast, inadequate communication can result in misunderstandings, misinterpretations, and a lack of clarity regarding project objectives and requirements (Wong et al., 2020; Ghobadi & Sepasgozar, 2020). Panchal et al. (2023) additionally emphasised the necessity of a thorough comprehension of the causes of cost overruns and delays in order to improve project management practices.

The AEC industries could benefit greatly from combining VR with BIM. However, the implementation of these technologies is encountering challenges. Integrating VR into BIM solutions has the potential to improve communication and problem-solving in collaborative projects, providing a way to address the ongoing issues in the industry. Sampaio (2018) highlights the natural development of VR technology in the BIM design process, facilitating

more efficient collaborations between designers and builders. Utilising VR enables teams to comprehend intricate designs and spatial relationships, hence enhancing comprehension of project needs and diminishing the potential for misunderstandings (Panya et al., 2023).

Although the effectiveness of integrating VR with BIM is well-known, more research is needed in this area (Zaker & Coloma, 2018). The main obstacle to the broad use of these technologies is the need for more understanding and awareness of the benefits they provide to the building industry. Botton (2018) and Wolfartsberger et al. (2018) have pointed out that a lack of understanding regarding VR-BIM integration is a major barrier. Amin (2022) observes that, despite these benefits, the combination of BIM and VR has not yet attained industry standard status, as numerous practitioners remain unacquainted with the appropriate utilisation of both technologies. The lack of comprehension may result in the underutilisation of the advantages provided by BIM-VR integration, including enhanced communication of design decisions among team members.

The Malaysian government adopted BIM in 2007; however, there is still a requirement for increased acceptability and expertise among contractors. The limited dissemination and utilisation of this technology provide obstacles to sharing knowledge, impeding its wider acceptance. The sluggish pace of BIM adoption in Malaysia could hinder the integration of advanced technologies such as virtual and augmented reality, which are essential elements of extended reality technologies. It is essential to overcome these obstacles in

order to fully utilise VR and BIM in revolutionising the Malaysian construction industry.

1.4 Research Questions

The research questions help establish the study's focus and develop the research objectives from the research questions obtained. These questions influenced the steps taken in conducting this research. The research questions of this study are as follows:

- What are the potentials of virtual reality technology for the construction industry?
- What are the primary issues that often occur at the construction site in Malaysia?
- How can implementing virtual reality and BIM technology reduce the construction site challenges?

1.5 Research Objectives

The research objectives can be established based on the research questions to conduct the research and study. The specific research objectives are as follows:

- To study the potential usage of Virtual Reality (VR) technology in the construction industry in Malaysia.
- To identify the primary issues that arose at the construction site in Malaysia.

- To develop a framework for using VR with BIM in the construction industry.

1.6 Scope and Limitations of Research

This research significantly delves into the challenges pervasive in the construction industry within Malaysia, with a specific emphasis on the Klang Valley area. The main problems in the Malaysian construction industry include time and cost overruns, safety hazards, and communication deficiencies. The project aims to address the stated obstacles by integrating BIM with VR to mitigate these issues and unlock their potential effectively. It highlights the need for more investigation in both study and practical use to understand the transformative effect of this combination completely.

The scope acknowledges that integrating VR-BIM has the potential to address multiple challenges in the construction sector but also has limitations. The limits create difficulties that require people to undergo additional training, possess knowledge of the technologies used, and use updated equipment. An important factor highlighted is the significant financial investment needed for the successful execution of this initiative in the Malaysian construction sector.

The study strategically focuses on surveying Grade 7 (G7) contractors in Malaysia. This intentional decision is based on the recognition that certain contractors have more significant financial resources, leading them to be more likely to adopt BIM and VR technology in their construction projects than other

companies. The statistical analyses in the report are based on the survey data, offering significant insights into how BIM- VR may be used to address construction difficulties effectively.

The research covers a wide range of topics within a specific geographic area and recognises the limitations, especially related to technology and financial matters. This sets the study in a practical framework that aims to find solutions while acknowledging challenges in the stages of integration.

1.7 Significance of the Research

The research on the integration of BIM and VR technologies in the Malaysian construction industry is significant because it has the potential to bring about significant changes in the construction industry. The construction sector in Malaysia, similar to its global counterparts, faces ongoing difficulties such as time and cost overruns, communication difficulties, and safety concerns at construction sites. This research can change industry processes and outcomes by tackling these difficulties using technological integration.

The research's significance lies in the vital component of technological improvement in construction. Gaining a comprehensive understanding of and discovering solutions to the challenges that prevent the successful adoption of BIM and VR technologies is crucial for guiding the construction sector towards a future marked by increased technological development.

The research seeks to map out a path that improves the industry's technological environment and contributes to a more efficient, cost-effective, and innovative construction system. An essential consequence of this research is its ability to alleviate difficulties faced by the sector. The study aims to uncover the barriers that impede BIM and VR adoption. Doing so offers practical insights that can result in more efficient execution of projects, decreased expenditures, and enhanced project outcomes. This has the capacity to enhance individual construction projects and reconfigure the industry's atmosphere.

Moreover, the research is significant in the field of workforce development. A knowledge and understanding gap among construction workers is a crucial feature of this study. Addressing this deficiency is crucial for successful technology integration and has broader consequences for workforce development. The research findings can be used to develop focused training programmes that provide construction workers with the essential skills, promoting a more proficient workforce in technology.

Integrating BIM and VR can provide a significant competitive edge to the Malaysian construction industry. Situated at the forefront of technological advancement, the sector has the potential to draw in investments and enhance its competitive edge on both domestic and international levels. Hence, this study holds economic implications that surpass the confines of the construction industry, consequently boosting the overall economic progress of the nation.

From an academic perspective, the research enhances the current knowledge by offering detailed insights into the specific difficulties encountered by the construction industry in Malaysia. This contribution establishes a basis for future research and enables the comparison of global construction practices. The research has significant academic importance as it can influence scholarly discussions on adopting technology in the construction industry.

Finally, the research aligns with worldwide patterns that advocate for innovation and sustainable development. The incorporation of BIM and VR not only tackles current obstacles but also positions the construction sector to adopt eco-friendly and resource-efficient building methods. This research adds to the overall discussion on sustainable development in the construction industry.

Overall, the study on the possible incorporation of BIM and VR technology in the construction sector of Malaysia has numerous complex implications. The construction sector and beyond can significantly benefit from its ability to bring about significant change, improve technological capabilities, address industry challenges, cultivate the workforce, gain a competitive edge, make academic contributions, and align with sustainable development goals. This makes it a crucial undertaking with wide-ranging implications.

1.8 Summary of Chapter

This study acknowledges the restricted implementation of BIM and VR integration in Malaysia's construction sector, mainly attributed to inadequate research. The building industry in Malaysia has prevalent obstacles, such as delays and increased expenses, safety risks, and communication difficulties. Integrating BIM and VR technologies could potentially mitigate these issues.

This chapter has presented a succinct summary of the study's goals, encompassing the issue statement and research questions crucial for fulfilling the research objectives. This research focuses exclusively on G7 contractors operating in the Klang Valley area of Malaysia. These contractors were selected based on their significant financial resources, enabling them to embrace and readily use new technology in their building projects.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers an in-depth review of the issues encountered at construction sites in Malaysia and the potential of integrating VR and BIM technologies. A literature review comprehensively analyses all published materials about a specific topic, theory, or study matter. The primary aim of the review is to identify the predominant construction challenges in Malaysia to implement VR-BIM technology to mitigate these concerns. In addition, this chapter provides a detailed analysis and finalises the results of the examined literature, resulting in a thorough comprehension of the conceptual research model.

2.2 Existing Challenges in Malaysian Construction Sites

The construction industry in Malaysia has become a vital sector in recent years. This is mainly because of its flexibility and capacity to connect with other sectors forward and backwards (Chia et al., 2014; Khan et al., 2014; Berawi et al., 2019). Khan et al. (2014) reported that the construction sector in Malaysia has undergone substantial modernisation, improved efficiency, and enhanced technology capabilities. This advancement has facilitated the expansion of local businesses by completing more intricate and substantial infrastructure

projects that require state-of-the-art technologies. The industry comprises various components, including multiple contractors, workers, developers, client organisations (governmental and private), management staff, engineering consultants, architectural consultants, surveying consultants, manufacturers, material suppliers, and plant hirers. Since Malaysia gained independence in 1957, the construction industry in the country has seen significant transformations. It has transitioned from a low-tech sector heavily dependent on manual labour and skilled craftsmanship to one that can now construct contemporary buildings and infrastructure. The evolution process is characterised by the widespread utilisation of mechanised manufacturing techniques and the integration of cutting-edge technologies (Kamal & Flanagan, 2012).

The construction sector in Malaysia has experienced significant expansion in recent years; nonetheless, this expansion has been accompanied by various challenges. Many studies argue that Malaysia's construction industry faces obstacles that impede its efficient operational performance. The construction sector commonly has time delays and cost overruns, which must be identified and resolved (Aziz & Hafez, 2013; Koushiki et al., 2005). The Malaysian construction sector requires assistance in effectively implementing government policies, particularly concerning integrating and using emerging technology to enhance industry performance and productivity. This implementation process poses significant hurdles. The research conducted by Ibrahim et al. (2010) revealed that the inadequate utilisation of technology has been recognised as a possible element contributing to the industry's low

productivity. The government's current methods and procedures, primarily overseen by the Construction Industry Development Board (CIDB), must be altered to correctly address and acknowledge the substantial issues contractors face. These problems pertain to the contractors' capacity to embrace and employ technology and their capability to benefit from the most recent technical progress. The guidelines and recommendations suggested have minimal impact during the formulation phase and often need help during implementation.

2.2.1 Causes of Overrun Issues in Construction

Construction cost and time overruns are persistent challenges that affect projects worldwide, often leading to financial losses, delayed project delivery, and strained relationship among stakeholders. These overruns can stem from a variety of factors, including poor project planning, inaccurate cost estimation, unforeseen site conditions, and ineffective communication among teams. Addressing these issues requires implementing better project management practices, such as integrating technologies like BIM and adopting proactive risk management strategies. By tackling the root causes of overruns, the construction industry can improve efficiency, minimise delays, and deliver projects on time and within budget.

2.2.1.1 Cost Overrun Impacts in Construction

Cost overrun denotes the situation wherein the actual expenses of a project exceed the initially estimated or allocated cost. Himansu (2011) defined "cost overrun" as the difference between the actual expenses incurred during a project and the initial budget allotted. Recent studies have shown an increasing worry over cost overruns in the building business (Cindrela Devi & Ananthanarayanan, 2017). Construction projects have consistently exceeded their allocated budgets despite the growing importance of the consequences. The economic ramifications of cost overruns can be significant, influencing not only the specific project but also the wider economy. Ozcan-Deniz (2019) noted that projects completed under budget are uncommon, and the consequences of cost overruns can create tension among clients, project managers, and contractors.

According to Vaardini et al. (2016), cost overruns in developing nations are far more noticeable, frequently exceeding 100% of the original project cost, primarily due to insufficient resource management. It is essential to exercise cost control to ensure that building projects adhere to the planned budget. Consequently, it is essential to execute project cost management, encompassing resource allocation, cost estimation, cost monitoring, and cost allocation, to ensure adherence to the predetermined project budget.

Chitkara (2011) identifies five critical factors that may be managed and lead to project cost overruns. The factors encompass, but are not restricted to: [1] The

project formulation requires enhancement due to poor field inquiry, insufficient project information, erroneous cost estimates, lack of experience in project formulation and feasibility analysis, and inadequate project assessment, leading to an erroneous investment decision. [2] The implementation planning requires enhancement, encompassing insufficient allocation of time, resources, and equipment, inability to anticipate interconnections, poor organisational structure, and deficient cost planning. Insufficient contract planning and management, namely in pre-contract activities and post-award contract oversight, are two critical factors that exacerbate problems in contract execution. Furthermore, inadequate project management during implementation may lead to issues such as poor task execution, delays, modifications in project scope and location, as well as legal and security complications.

Cost overruns are common construction projects, referring to expenses exceeding the initial budget. However, the magnitude of these overruns might differ from one project to another (Azis et al., 2013). Wong et al. (2020) highlighted that cost overruns lead to cash flow issues and diminish trust among project stakeholders, thereby hindering future collaborations. Payment delays, challenges in securing adequate finances, and increases in the project's scope are the primary factors that commonly lead to budget overruns in building projects. Furthermore, the occurrence of time overrun can be attributed to the primary factor behind cost overrun, both critical indicators of a project's triumph or downfall. Roumeissa (2019) emphasised that delays frequently occur in building projects, typically due to inadequate scheduling

and project management. When project timelines are delayed, they may be accelerated or the completion schedule prolonged, both of which can result in increased expenses.

In Malaysia, the completion rate of government-funded projects within their original budgets were 46.8% in 2016, while privately funded projects within their original budgets were 37.2% (Sambasivan & Soon, 2007; Ibrahim et al., 2010). Wibowo (2024) further emphasises that government-induced hazards, including bureaucratic inefficiency and regulation alterations, can complicate project management and result in cost overruns. Additionally, cost overruns can lead to public dissatisfaction, particularly in government-funded projects, where taxpayers are responsible for the financial burden of mismanagement (Catalao et al., 2021).

A common cause of cost overruns in Malaysian building projects is imprecise cost estimation. Insufficient material procurement management and erroneous cost estimations are important variables contributing to budget overruns (Juan et al., 2018). When preliminary cost evaluations neglect to include all essential expenditures, projects are prone to surpass their budgets as actual costs emerge during implementation. Inadequate planning and scheduling are often identified as major factors leading to cost overruns. Shah emphasises that inadequate planning, poor site management, and insufficient contractor expertise are significant problems impacting project prices in Malaysia (Ozcan-Deniz, 2019). Inadequate project planning might result in delays and heightened expenses as teams rush to resolve unexpected challenges.

According to Patil (2017), a significant number of contractors need to gain the ability to strategize for on-site operations efficiently, coordinate labour, and oversee and regulate ongoing activity. Therefore, it is imperative for those overseeing building projects in Malaysia and other locations to address the issue of cost overruns carefully. The solution depends on cost control procedures such as cash flow management and project accounting, which are applied as components of project cost management to guarantee that the project remains within its designated budget (Vaardini et al., 2016). Since most cost overruns in construction projects are caused by inadequate resource management, implementing an efficient resource management system is one potential option to mitigate the effects of cost overruns. Effective project management procedures, such as thorough planning, risk evaluation, and stakeholder involvement, are essential. According to Odeck et al. (2015), effective front-end management is crucial for successful project execution and can mitigate several planning mistakes that result in cost overruns.

2.2.1.2 Factors of Time Overrun in Construction

Assaf and Al-Hejji (2006) state that construction delays occur when a project takes longer to complete than initially planned. Time overruns in the construction sector provide a substantial problem, affecting project completion, expenses, and overall stakeholder satisfaction. The phenomenon is described by the prolongation of the project timeline beyond the originally established timetable, potentially resulting in budget overruns, stakeholder disagreements,

and a decline in project quality. The current situation has a harmful impact on all parties concerned, with the financial repercussions being most noticeable.

Research reveals that schedule overruns are common in both developed and developing countries, with research revealing that more than 40% of construction projects encounter these delays (Soomro et al., 2019). Factors contributing to these overruns are many, including insufficient planning, financial challenges, and unexpected site circumstances (Akhund et al., 2018; Eltoukhy & Nassar, 2021).

Nevertheless, it is essential to acknowledge that construction delays are not exclusive to Malaysia but rather a prevalent phenomenon worldwide. Numerous studies have identified several reasons leading to these delays, which can be classified into client-related, contractor-related, material-related, labor-related, and external factors (Adeleke et al., 2021; Latif, 2023). A survey revealed that over 17.3% of government projects in Malaysia are deemed "sick," signifying they have been postponed or abandoned for more than three months, underscoring the gravity of the issue (Latif, 2023).

Poor project management practices are one of the primary causes of delays in Malaysian construction initiatives. Studies indicate that poor planning, inadequate site management, and ineffective communication among stakeholders are common problems (Abdullah et al., 2018; Memon et al., 2011). The deficiency in competency among project managers has been recognised as a major factor leading to project delays (Moon et al., 2018). The

Malaysian construction sector has faced criticism for its dependence on antiquated contract types, which frequently intensify disputes and result in delays (Abdullah et al., 2018). The economic climate, encompassing inflation and variable material costs, has been identified as a contributing cause to delays in project deadlines (Fateh & Yee, 2021; Shahbaz et al., 2020).

The construction sector often attributes delay to decreased operational efficiency and production (Sanni-Anibire et al., 2020). The delays substantially and adversely affect the stakeholders' interests as they continuously lead to higher costs (AlSehaimi et al., 2013; Azhar & Choudhry, 2016). It is common for projects to be either expedited or prolonged in response to delays, which often leads to supplementary expenses. The success parameters of a project are significantly influenced by an efficient and expeditious management strategy. It prevents challenges from escalating and subsequently avoids delays in resolving them (Shrivastava & Singla, 2020).

The causes of time delays in construction projects are diverse, as delays frequently occur in nearly all construction operations. Furthermore, the extent of these delays exhibits significant diversity among different projects. The research by Yap et al. (2019) identified five primary factors contributing to project delays and inefficiencies: "insufficient planning and scheduling," "excessive client-initiated change orders," "inadequate site management and supervision," "incompetent subcontractors," and "financial difficulties encountered by contractors". The causes and factors primarily stem from management concerns, particularly the importance of efficient planning and

management in accelerating project schedules and making up for time lost during delays at different project stages (Sambasivan & Soon, 2007).

Multiple academic research has found that a lack of knowledge accumulation, namely the repetition of mistakes in consecutive projects, is the primary component that contributes to the long-lasting and difficult-to-solve nature of the problem (Love et al., 2018). It is crucial to acknowledge that if the underlying causes are not discovered and resolved, delays and extra expenses are highly probable in construction projects (Ahmad et al., 2014).

Garemo et al. (2015) asserted that most construction projects exceed anticipated costs and timeframes. The project's performance could be adversely affected by delays in the construction project due to various factors. A decrease in the efficiency and productivity of the workers characterises delays in a construction project. Delays in this domain can result in several issues, including litigation, escalated expenses, project stagnation, reduced productivity, profit losses, and contract terminations.

Furthermore, the correlation between time overruns and cost overruns is well-documented. Delays may require supplementary money to accelerate work or prolong project timelines, thus increasing total expenses (Roumeissa, 2019; Famiyeh et al., 2017). The relationship of time and cost overruns highlights the necessity for efficient project management solutions that concurrently address both aspects (Eltoukhy & Nassar, 2021; Helwande, 2023).

Proposed mitigation measures to address time overruns encompass greater contract administration, improved financial planning, and superior communication among stakeholders (Olawale & Sun, 2010; AlAmeri et al., 2020). The application of sophisticated project management methodologies and technologies can enhance scheduling and resource distribution, consequently minimising the probability of delays (Eltoukhy & Nassar, 2021). In addition, implementing contemporary project management approaches, such as BIM can improve stakeholder coordination and optimise project execution (Molarn, 2024).

2.2.2 Challenges in Safety and Communication Management

Management issues in construction are a critical factor affecting project success, often leading to inefficiencies, delays, and cost overruns. These issues can arise from poor communication, lack of coordination among stakeholders, inadequate planning, and weak leadership. In many cases, the complexity of construction projects amplifies the challenges. Ineffective decision-making, insufficient resource allocation, and failure to adopt modern project management tools can further exacerbate these problems.

2.2.2.1 Safety Risks in Construction

Safety hazards on construction sites are a significant concern due to the intrinsically hazardous nature of building activities. The construction business is acknowledged as one of the most dangerous sectors, characterised by a

significant frequency of accidents and injuries. Multiple studies have identified several variables contributing to safety dangers, including safety management procedures, inadequate training, and the physical environment of building sites.

A significant factor contributing to safety hazards is the absence of appropriate safety management systems. Studies demonstrate that numerous construction firms inadequately implement recognised safety management systems, resulting in heightened accident frequencies. The Malaysian construction industry reportedly faces challenges in executing comprehensive safety management measures, notwithstanding the presence of legislative frameworks. The deficiency in safety management is sometimes intensified by concealed hazards at building sites, resulting in unexpected incidents (Langni et al., 2019).

Employee training and awareness are essential in reducing safety hazards. Research indicates that augmenting employees' safety knowledge by training might markedly enhance their capacity to recognise and address possible hazards (Hasanzadeh et al., 2017). The creation of a favourable safety climate in organisations is associated with improved safety practices among employees (Chen et al., 2019). When employees believe that their safety is prioritised, they are more inclined to adopt safe practices, thereby diminishing the likelihood of accidents (Mosly & Makki, 2020).

The physical environment of building sites poses distinct problems that lead to safety issues. The closeness of workers to heavy machinery presents considerable hazards (Teizer et al., 2010). The ever-changing environment of building sites, marked by continual alterations in layout and activity, can lead to confusion and heighten the risk of accidents (Wang et al., 2022). The implementation of technologies like BIM hazard identification and risk evaluation, hence improving safety management procedures (Kim et al., 2020; Li & Zhou, 2017). Furthermore, the incorporation of lean construction concepts has demonstrated the enhancement of safety through the reduction of waste and the optimisation of workflow efficiency (Bajjou et al., 2017). Lean tools facilitate the identification of potential hazards and ensure compliance with safety regulations during the construction process. This proactive safety management strategy mitigates accident risks and cultivates a safety-oriented culture among employees.

The configuration of the construction elements is essential in ascertaining the project's overall success. The advancement of subsequent construction activities, the efficiency of their execution, the overall cost implications, the transportation distance of building materials, and the security measures implemented at the site are all directly influenced by it (Ning et al., 2018; Sanad et al., 2008). Research by Malekitabar et al. (2016) and Ning et al. (2018) reveals that a significant number of accidents can be effectively addressed by straightforward design modifications. These improvements effectively eliminate the risks accountable for 46.8% of these incidents. Consequently, enhancing safety management requires an increased emphasis on

preventative strategies. The safety manager is required to conduct daily, weekly, and monthly inspections to assess the effectiveness of preventive measures and identify any potentially dangerous behaviours shown by personnel. During safety inspections, the safety manager must painstakingly document any hazardous conditions or inadequate implementation of preventive measures. This knowledge should thereafter be communicated to relevant industries to mitigate the risk of accidents and fatalities (Choudhry et al., 2008).

Mitigating hazards at construction sites necessitates a diversified strategy encompassing robust safety management systems, extensive training programs, and the integration of cutting-edge technologies. By cultivating a favourable safety culture and executing proactive safety strategies, the construction sector can markedly diminish accident occurrences and enhance overall worker safety.

2.2.2.2 Impact of Communication Management on Construction

As defined by the Project Management Body of Knowledge Guide, communication in the construction sector is the exchange of project information and procedures to create a clear and understandable connection between the sender and the recipient. The Project Management Body of Knowledge Guide recognises project management as a critical knowledge area in project management. This knowledge domain covers the essential procedures to ensure the prompt and appropriate creation, gathering, dissemination, storage,

retrieval, and final disposal of project information. Furthermore, communication is an essential component of project management that influences and affects all other aspects (Olaniran, 2015).

Effective communication management in the construction sector is essential for guaranteeing project success, improving safety, and promoting collaboration among stakeholders. The construction industry is marked by its intricacy, including various stakeholders like contractors, subcontractors, clients, and suppliers, all of whom must communicate efficiently to meet project goals. Studies indicate that inadequate communication might result in misconceptions, delays, and elevated expenses, necessitating the implementation of effective communication techniques (Muneer et al., 2022; Kania et al., 2020).

An essential advantage of proficient communication management is its beneficial effect on project success. A study demonstrated that explicit communication concerning project scope and objectives substantially enhances the success of building projects (Muneer et al., 2022). This corresponds with findings that underscore the significance of communication in promoting cooperation and collaboration among project participants (Malik et al., 2021). Moreover, good communication has been associated with enhanced safety results on construction sites. Effective safety communication between management and employees is essential for improving safety practices and adherence, hence potentially decreasing the occurrence of accidents (Alfayez, 2021; Pandit et al., 2018). Conversely, a failure to communicate hinders the necessary collaboration among those involved,

resulting in mistakes, omissions, conflicts, and feasibility issues that require further revisions (Yap & Tan, 2021). Many miscommunications often necessitate revisions at various stages of a project's duration, leading to additional workforce and costs. Successfully completing the building project requires a shared comprehension of the information exchanged between both parties.

The significance of technology in enhancing communication management is vital. The amalgamation of BIM and supplementary digital tools has demonstrated an improvement in information dissemination and collaboration among project stakeholders (Herzanita et al., 2022; Magaba et al., 2015). These technologies facilitate instantaneous communication and documentation, permitting expedited answers to emerging concerns, thus reducing delays and enhancing overall project efficiency (Chen et al., 2014). Furthermore, the implementation of web-based communication systems can enhance the distribution of safety information, which is crucial for ensuring a secure working environment (Herzanita et al., 2022).

Furthermore, enhancing communication facilitates collaboration, a crucial element in developing trust, easing collaborative decision-making, and promoting effective involvement. Consequently, this minimises the need for alterations and revisions during the building phase, guarantees compliance with regulations and standards, improves the quality of outputs, and reinforces project management (Yap et al., 2019). The interdependence of communication, trust, and information sharing significantly impacts the

collective learning process among team members, both inside individual projects and across several projects. Key determinants of project success encompass knowledge, unwavering dedication, and proficient communication (Yong & Mustafa, 2013).

2.3 Potential of Virtual Reality Technology in Construction

Since the start of the 21st century, several technological devices, such as mobile phones, personal computers, all-in-one models, and standalone gadgets, have been equipped with wireless communication functionalities and integrated virtual reality characteristics. Virtual reality enables participants to engage in the study, immediately experience interactions, and meticulously assess a comprehensive virtual model, fostering total immersion (Bordegoni & Rizzi, 2011; Paes et al., 2017). Colquhoun (1999) first created a detailed classification method for the visualisation system to position VR. This taxonomy classifies the various levels at which the concepts of "virtual" and "real" converge to form a visualisation environment. Virtual reality technologies encompass visualisation techniques aimed at delivering a sense of complete immersion in a virtual environment. These technologies have lately garnered significant attention due to their ability to enhance communication in professional settings and communal areas (Wang et al., 2018). The graphic illustrates the global count of virtual reality users engaged with the technology from 2014 to 2018.

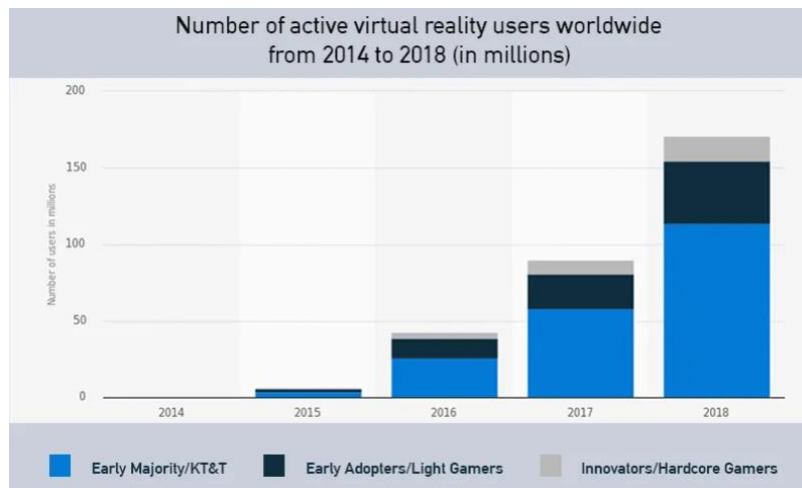


Figure 2.1: Number of active virtual reality users worldwide from 2014 to 2018 (in millions) (Source: Cleveroad, 2018)

Sampaio (2018) claims that virtual reality technology is an effective tool for monitoring the advancement of construction projects due to its capacity to facilitate active involvement in the building process and the visualisation of various stages of construction. Manipulating a 3D/BIM model in VR allows users to feel genuinely present in a potentially hazardous situation (Poussard et al., 2014). Before commencing construction, architects, engineers, and contractors may utilise VR to see project plans as digital depictions of the outcome. VR can be a valuable tool for understanding digitally designed architecture by offering a visually precise picture of the design object (Zaker & Coloma, 2018).

VR offers numerous potential applications in the AEC business, specifically in the domains of collaboration, project management, and education (Pratama & Dossick, 2019; Delgado et al., 2020). VR technology is an indispensable instrument for monitoring the construction sector's progress as it allows for active engagement and observation of various developmental phases. The

use of VR prior to the initiation of construction facilitates several applications, such as evaluating design options, showcasing proposals, detecting and correcting design flaws, and addressing construction and usability issues. VR enables critical stakeholders in the construction sector to enhance their comprehension of the project and their capacity to engage with each other.

VR technology has substantially progressed in its practical implementation across several industries. This emerging technology has proven its worth in the construction sector by efficiently decreasing the time spent on rework, improving financial savings, and identifying design flaws. Whyte & Nikolic (2017) states that virtual reality has multiple uses in the construction sector, such as design, collaborative visualisation, and enhancing the construction process. It functions as a powerful tool for architectural design, providing the ability to manipulate 3D visualisations in real time. These visualisations can be studied together to analyse various phases of the construction process.

The integration of VR technologies in the construction industry has the potential to be widely used throughout all stages of a project, including the design, construction, and post-construction phases. Researchers have extensively studied various VR applications in the construction industry. These applications include visualisation and collaboration, safety management, and construction engineering education and training (Baton, 2018; Wolfartsberger, 2019; Du et al., 2018).

The AEC industry heavily relies on visual communication, and it is commonly recognised that the progress in VR technology has positively impacted this

industry (Kim et al., 2013). Delgado et al. (2020) found that the potential to improve the execution of building projects is a significant factor in the adoption of virtual reality (VR) and augmented reality (AR) in the construction sector. Moreover, these technologies can improve project understanding, efficiency, communication, and cooperation.

Behzadi (2016) conducted a study that demonstrated the advantages of virtual reality in project scheduling, communication, information retrieval, safety management practices, and labour hours. Although there is current study on the application of VR in many countries, further studies are required on its implementation in the building sector of underdeveloped nations. Emphasis should be placed on discovering methods to integrate VR technology inside this industry. A significant barrier to the integration of virtual reality technology in the construction sector is the prevalent perception that the technology remains in a developing stage and is not yet suitable for practical application.

2.3.1 Key Capabilities of Virtual Reality

The capabilities of VR in the construction industry are rapidly evolving, offering innovative solutions that enhance various aspects of project management, design, safety training, and stakeholder engagement. The integration of VR with BIM has further amplified these capabilities, providing immersive experiences that facilitate better decision-making and collaboration among project stakeholders. As the AEC industry continues to evolve, VR is becoming

an invaluable tool for improving project outcomes, from concept to construction and beyond.

2.3.1.1 VR's Immersive and Interactive Potential

Interactivity refers to the extent of the user's flexibility and control over the experience, as defined by Makransky and Peterson (2021). On the other hand, immersion can be understood as the level of sensory realism offered by VR systems, as described by Bowman and McMahan (2007). VR can provide deeply engaging experiences by replicating real-world surroundings and allowing users to engage with them actively. Recent studies indicate that virtual reality distinguishes itself through its exceptional level of immersion and interactivity (Johnson-Glenberg, 2018; Makransky & Peterson, 2021).

Moreover, VR enables users to engage seamlessly and instinctively with the simulated environment, utilising bodily movements, hand gestures, and head motions to navigate the virtual realm and interact with its elements. The collaborative potential of the virtual reality markup tools, with their ability to create a fully immersive 360-degree environment, surpassed that of the BIM markup tools in terms of fostering teamwork (Asl & Dossick, 2022). In addition, proponents argue that the self-centred perception of spaces and users' comprehension of the proportional dimensions of those spaces about their size will be enhanced by having the ability to view the entire model, as is possible in a completely immersive system like head-mounted displays or room-scale virtual reality (Kalisperis et al., 2002).

Recent studies demonstrate that virtual reality's ability to provide an immersive and captivating experience sets it apart from conventional educational methods (Makransky & Peterson, 2021). While both immersion and interaction augmented the sensation of physical presence, it was clear that the influence of interaction was crucial to the experience and embodied learning in environments with moderate levels of immersion. Advancements in virtual reality technology enable designers to evaluate and interact with equipment models and prototypes in a more realistic environment.

2.3.1.2 VR Simulations in Construction

Simulation refers to the process of representing the behaviour of a system using software, as defined by Mourtzis et al. (2014). VR simulation involves replicating real-world settings, activities, and events using computer software. A VR simulation offers an authentic setting where users can practise and refine their skills without any potential hazards. VR is an advanced computer technology for immersive virtual environments. Enabling users to engage with virtual environments through sensors is achieved by simulating the real world.

VR is a technology that immerses the users in a computer-generated environment, facilitating natural interaction through the senses of sight, sound, and touch (Quint et al., 2015; Jensen & Konradsen, 2018). Sampaio (2018) argues that VR technology allows users to completely engage in a 1:1 scale, providing an authentic feeling of being present in a space that has not yet been

constructed. This enables users to explore the virtual world by physically moving through the model and interacting with objects in real-time. VR simulations can be remarkably realistic and immersive, evoking a sense of being present within the simulated environment. By offering a secure and authentic setting, they can facilitate the enhancement of learning and the development of skills.

Hu et al. (2018) introduce a virtual reality (VR) framework to represent and simulate work processes. Additionally, it enables the visualisation of analytical data from various computer-aided engineering (CAE) programmes. Simulation in VR applications can effectively verify logic, resolve conflicts, and minimise costs, especially during a construction project's planning and design stages (Karagiannis et al., 2020). The convergence of highly engaging and user-friendly VR technology and the secure environment of a simulated world creates a potent instrument (Karagiannis et al., 2020). The rationale behind this method is illustrated in the subsequent diagram.

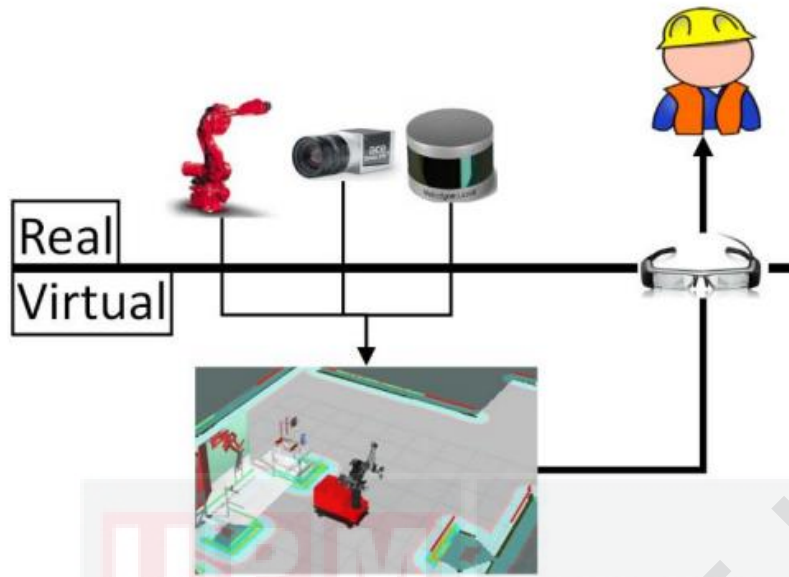


Figure 2.2: Simulation and VR applications approach
(Source: Karagiannis et al., 2020)

According to the illustration by Karagiannis et al. (2020), displayed in Figure 3 above, the simulation seeks to recreate the real-life setting accurately, including the resources meant for the operator's utilisation. Simultaneously, the VR application enables users to visually perceive the surroundings using simulated sensors and interact with them via VR interfaces.

2.3.1.3 VR for Training and Communication

The incorporation of virtual reality in education, especially within construction and engineering, has surfaced as a revolutionary method to improve learning outcomes and communication. Virtual reality technologies, particularly head-mounted displays (HMDs), enable students to engage in simulated environments that mirror real-world situations, which is especially advantageous in disciplines necessitating practical experience, such as

construction and engineering (Huang & Roscoe, 2021; Jensen & Konradsen, 2017).

The most common uses of VR simulations in education include design visualisation, construction safety instruction, equipment operation, and structural analysis. Thus, educational VR applications need to provide direct and consistent solutions to fully achieve the mentioned benefits. Considering the pedagogical, methodological, and theoretical aspects, this highlights numerous conceptual and empirical challenges in how VR is understood and justified in construction education (Ventura et al., 2022).

A notable benefit of employing VR for education is its capacity to replicate perilous conditions that students cannot safely encounter in reality. This immersive experience not only deepens comprehension of intricate topics but also equips students for real-world challenges by enabling them to practise decision-making in a controlled environment (Campos et al., 2022).

Research demonstrate that virtual reality can markedly improve educational results by offering engaging and immersive experiences absent in conventional teaching approaches (Mihaescu, 2023; Garduño et al., 2021). By creating a multisensory learning environment, VR enhances students' comprehension of abstract concepts, which is vital in technical disciplines such as construction where spatial awareness is critical (Rashid et al., 2021).

Immersive VR has shown its potential to improve productivity in design review meetings and model inspections, as seen by recent advancements in multi-

user sessions (Heinonen et al., 2022). Incorporating multi-user co-presence in a virtual reality model increases its value by facilitating improved information sharing and collaboration among participants. Johansson and Roupe (2022) assert that attributes including a 1:1 scale, stereo vision, and the ability to see and indicate others' perceptions enhance communication and understanding. Integrating multiple languages into virtual reality software overcomes language boundaries, removing a significant hindrance to efficient collaboration.

2.3.1.4 Design and Visualisation through VR

The utilisation of VR in the construction sector has profoundly altered design and visualisation approaches, improving both educational and practical results. Virtual reality technologies enable immersive experiences that permit stakeholders to visualise projects in three-dimensional space, enhancing comprehension and communication during the design and construction phases.

The key advantage of VR in construction design is its capacity to improve visualisation capabilities. Conventional two-dimensional representations frequently inadequately express the spatial relationships and intricacies of a project. Conversely, VR enables architects, engineers, and clients to engage with 3D models in real-time, enhancing understanding of design purpose and usefulness (Juan et al., 2018). Juan et al. (2018) also shown that virtual reality may efficiently evaluate design concepts and program developments, mitigating problems such as pipeline collisions during the design process. This

capacity is essential for reducing errors and guaranteeing that all stakeholders possess a comprehensive understanding of the project prior to the commencement of construction.

Besides, the combination of BIM with VR has significantly improved the design process. BIM delivers comprehensive data regarding the physical and functional attributes of a project, whereas VR presents an immersive environment for examining these models (Juan et al., 2022). This integration facilitates more simple management of design modifications and improves communication across project teams. Keung et al. (2021) demonstrated that utilising VR as a medium for content delivery enhances user engagement by immersing individuals in the design environment, so effectively eliminating distractions from the physical realm. This immersive experience facilitates design evaluations and enhances collaborative decision-making, allowing various stakeholders to engage with the model concurrently (Zaker & Coloma, 2018; Truong et al., 2021).

Besides enhancing design visualisation, VR is also essential for construction planning and safety training. Through the simulation of construction processes, virtual reality enables teams to visualise operational sequences and detect potential safety concerns prior to their occurrence (Wen & Gheisari, 2020; Selvaprasanth et al., 2021). This proactive strategy for safety training is crucial in the construction sector, frequently marked by hazardous conditions. Rashidi et al. (2022) proved that employing VR for construction planning markedly

enhanced usability, accuracy, and speed relative to conventional approaches, underscoring its efficacy in training contexts.

Furthermore, the application of VR transcends design and planning; it also improves stakeholder participation and communication. VR offers a collaborative digital environment, enabling clients, architects, and contractors to jointly examine the project, so enhancing conversations and feedback through a more interactive approach (Wen & Gheisari, 2020; Truong et al., 2021). This collaborative environment fosters improved alignment of expectations and a more unified project vision, eventually enhancing client satisfaction and minimising project delays.

2.4 Building Information Modelling in Construction

Building Information Modelling (BIM) is an integrated technique enabling construction stakeholders to digitally visualise a project's essential physical and functional attributes prior to the commencement of construction (Latiffi et al., 2015). The main objective of BIM is to augment the planning, design, and quality of construction projects, hence facilitating enhanced efficiency and diminished errors. BIM employs throughout several phases of a construction project, encompassing pre-construction, construction, and post-construction (Ying & Kamal, 2021).

Nonetheless, despite its benefits, the implementation of BIM poses problems. Issues such as the initial implementation cost, the necessity for training and

education, and reluctance to change among industry professionals can impede its extensive adoption (Khallafallah, 2023). Despite existing hurdles in its implementation, the potential advantages of BIM render it a crucial instrument for contemporary construction methodologies. As the industry progresses, adopting BIM will be essential for enhancing productivity and sustainability in construction endeavours.

2.4.1 Current State and Adoption of BIM in Malaysia

BIM is increasingly acknowledged as a vital technology in the Malaysian construction industry, designed to improve project efficiency, collaboration, and sustainability. The implementation of BIM in Malaysia has progressed significantly since its debut, with numerous stakeholders, including governmental bodies and private companies, acknowledging its prospective advantages. BIM was initially introduced in Malaysia by the Public Works Department (PWD) in 2007, with significant encouragement for its utilisation in construction projects (Latiffi et al., 2016). Recent statistics reveal that the adoption rate of BIM among construction firms in Malaysia is approximately 17%, markedly lower than the rates in industrialised nations like the United States and Singapore, where adoption exceeds 70% (Naing et al., 2022).

Notwithstanding the acknowledged advantages, numerous obstacles impede the extensive use of BIM in Malaysia. Significant obstacles comprise substantial initial capital expenditures, ambiguous return on investment (ROI), and the necessity for comprehensive training and education for industry

professionals (Al-Mohammad et al., 2022; Ismail et al., 2022). Smaller construction firms encounter challenges in implementing BIM owing to constrained resources and skills (Ismail et al., 2022). Moreover, according to Waqar et al. (2023), the absence of standardised processes and rules for BIM deployment can result in inconsistencies in its application across different projects and the cultural opposition to transformation within the constructor sector is a considerable obstacle. Numerous stakeholders are familiar with conventional procedures and many exhibit reluctance to adopt a digital workflow, thus obstructing the incorporation of BIM into their practices.

In order to encourage BIM adoption in Malaysia, it is crucial to tackle the current obstacles through focused activities. This encompasses offering financial incentives for companies to invest in BIM technologies, creating extensive training programs to enhance workforce skills, and formulating explicit norms and standards for BIM implementation (Saf'a et al., 2023; Ismail et al., 2022). Furthermore, cultivating a collaborative culture among industry players can enhance the exchange of best practices and experiences, ultimately resulting in a more efficient integration of BIM in building projects.

2.5 Combination of VR and BIM for Enhanced Construction Practices

The AEC industries employ VR and BIM for diverse objectives. VR is highly regarded for its superior capacity to convey dimensions and complex details compared to traditional two-dimensional visualisation (Johansson & Roupe, 2022). The critical principle of BIM revolves around creating and manipulating

design data. Simultaneously, the virtual reality components pertain to the visualisation and interaction with these simulated surroundings. Kim & Ko (2019) state that incorporating VR technology in the assessment, display, and proof of concept stages of architectural design provides occupants and architects with an enhanced "roaming experience". Integrating VR into BIM technologies can enhance communication and problem-solving effectiveness in collaborative and interactive projects. Moreover, VR can successfully address difficulties in information retrieval and presentation.

BIM involves creating and using three-dimensional objects that contain valuable property information, specifically pertaining to the necessary data for a construction project at every stage of its lifespan. The life cycle has distinct phases: design, planning, construction, operation, and maintenance (Gheisari & Irizarry, 2016; Song et al., 2018). BIM-enabled VR relies on the model, specifically focusing on data connection. Visualisation in BIM is widely acknowledged for its significance, as it enables users to access BIM data and conduct real-time analyses of parameters such as cost and material type through immersive visualisation environments (Wang et al., 2011). This enables the development of efficient architectural designs without necessitating personal presence at the construction site. An instance of utilising BIM-enabled VR is enabling users to transform architectural design concepts into a three-dimensional virtual setting. This technique eliminated the limitations of assessing two-dimensional representations and enabled users to evaluate the design space effectively.

Sampaio (2018) argues that incorporating VR technology into the design process is a natural advancement for BIM as it can enhance the overall quality of different constructed settings. Integrating BIM and VR allows designers and builders to have more effective discussions about possible conflicts and design flaws before starting actual construction. The combination of BIM and VR technology can create a robust system that can accurately simulate different phases of building development, hence encouraging the implementation of sustainable design principles (Hatta et al., 2022). Zima et al. (2020) found that using new technologies can augment and enhance the precision of engineering cost estimating (ECE) procedures. The benefits of combining VR and BIM, as Sampaio (2018) outlined, are summarised in the image below.

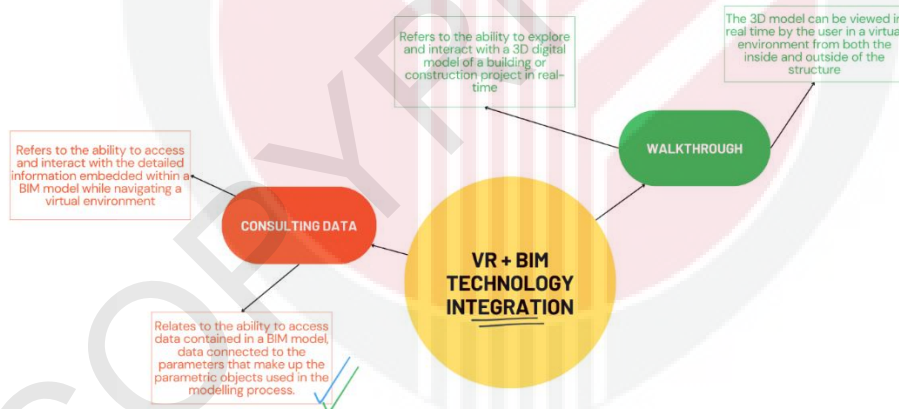


Figure 2.3: Ways of interaction with 3D/BIM models
(Source: Sampaio, 2018)

Integrating BIM and VR has been extensively acknowledged for its many benefits. Nevertheless, the difficulty is inefficiently transmitting data from BIM to rendering engines compatible with VR, impeding the mainstream use of BIM and VR technologies (Boton, 2018; Wolfartsberger et al., 2018). Sampaio

(2018) states that incorporating interactive elements of VR into 3D/BIM models during the construction process allows for virtual testing and correction of construction projects before their physical execution. Integrating BIM with VR can save costs by using realistic simulations, hence minimising the possibility of costly errors during on-site operations. According to Wang (2021), the combination of BIM with VR technology provides notable benefits in terms of virtual visualisation, information interaction, and management coordination. Combining these elements makes it possible to forecast and actively manage many variables in the construction process, thereby bringing a novel approach to project management in construction. The combination of digital information simulation, BIM and VR has become a robust and influential tool in construction project management.

2.5.1 Capabilities of VR-BIM Integration

VR has multiple applications in the AEC industry. It may promote cooperation, improve project management, and aid educational efforts (Pratama & Dossick, 2019; Delgado et al., 2020). Using VR technology in the context of BIM can improve many procedures. Incorporating VR into BIM can benefit design and construction procedures. The benefits encompass heightened efficacy, enhanced precision, and reduced expenses. Furthermore, it can improve communication among project participants, such as workers and stakeholders, generating a more captivating and stimulating experience for all involved.

Since its debut, BIM software has constantly led to improvements in the AEC and facility management (FM) industry. The main goal of BIM is to facilitate the smooth transfer of data between different disciplines involved in building construction (Carvalho et al., 2021; Porwal & Hewage, 2013; Ren et al., 2021; Scorpio et al., 2022; Xu et al., 2021). Real-time data visualisation allows for the upkeep of current BIM models, leading to improved usability and a more immersive experience. The adoption of this method shows potential in minimising deficiencies in spatial intelligence, augmenting comprehension of projects, and facilitating enhanced communication in design (Alizadehsalehi et al., 2020; Carrasco & Chen, 2021; Heaton et al., 2019; Kim et al., 2021; Sidani et al., 2021; Spaeth & Khali, 2018; Xu et al., 2021).

2.5.1.1 Boosting Collaboration with VR-BIM

In the past twenty years, VR has gained significant popularity as a collaborative tool in the AEC industry (Asl & Dossick, 2022). VR enables excellent communication among stakeholders in the construction industry by boosting design visualisation and enhancing everyone's comprehension of the project (Sampaio, 2018). Virtual reality technology enhances distant teamwork by facilitating improved participant communication and coordination. These factors can optimise communication, streamline coordination, and minimise errors. The emergence of Collaborative Virtual Environments (CVEs) can be attributed to the intuitive interactions in 3D space and the perception of being in the same physical area. In CVEs, users are virtually positioned together and can engage with one another (Bouchlaghem et al., 2004).

Recent research has additionally demonstrated that VR possess significant potential as a decision-making tool. According to Asl and Dossick (2022), VR systems that allow multiple users can enhance dialogue, comprehension, and teamwork. These systems enable users to record voice messages and use the markup tool to draw and explain conflicts and resolutions, thus facilitating asynchronous collaboration. These multi-user features allow for the acquisition of critical skills without requiring a centralised meeting location for all participants. Consequently, there will be a reduction in both the time and financial resources allocated for transportation to the construction site. Utilising VR for interaction and collaboration in BIM can enhance construction efficiency, precision, and safety, resulting in reduced expenses and improved project excellence.

2.5.1.2 Cost Reduction and Efficiency Improvements

Evaluating the expenditures linked to incorporating VR technology into BIM is vital, guaranteeing that the benefits, such as improved productivity, cost savings, and overall project quality, outweigh the expenses. Builder Magazine (2018) states that VR solutions can reduce building expenses by as much as 90%. This can be ascribed to their capacity to offer project owners accurate representations of the development, facilitating the detection and settlement of any disputes or required modifications prior to the start of construction. Before the physical construction stage, VR enables a thorough comprehension of several elements, including room dimensions, presentation methods, arrangement choices, material alternatives, and budgeting. This helps avoid

the need for construction modifications and reduces financial and temporal excesses.

VR can decrease the cost of site visits and client meetings by eliminating the necessity for prototypes and mock-ups. By employing BIM and VR in the AEC sector, teams can minimise the duration of coordination meetings in comparison to conventional paper-based methods while simultaneously enhancing overall satisfaction. Experts in AEC have observed that using VR applications improves clients' ability to visualise designs and track construction progress at an earlier stage. This results in cost savings on materials and a reduced workforce for a given project. VR tours can be utilised on a BIM model to assess the maintenance schedule from a facility management standpoint (7D/BIM model) or to evaluate the constructability of the design from the perspective of the project team (Sampaio, 2018). Consequently, it is feasible to economise time and resources by reducing the frequency of coordinating meetings.

Sampaio (2018) asserts that tangible disputes may occur during the typical progression of building, perhaps resulting in additional costs and time setbacks. Utilising 4D/BIM, the team may systematically examine any possible conflicts by consulting the BIM model at every phase of the construction process. Integrating VR into a BIM tool can enhance the model's functionalities and mitigate expenses associated with real-world construction by minimising costly errors made by personnel at the construction site.

2.6 Unlocking the Potential of VR-BIM for Addressing Site Issues

The challenges encountered on construction sites are not confined to Malaysia but have a global impact. Inadequate communication among construction workers and other stakeholders is a fundamental factor that contributes to numerous issues that can hinder productivity and damage a company's reputation. Communication deficiencies frequently give rise to problems such as excessive costs, delays, and safety issues at the construction site, necessitating rectification. Integrating VR technology can improve communication among construction workers, professionals, and stakeholders, effectively tackling and mitigating these prevalent difficulties.

Integrating BIM with VR can boost remote collaboration by promoting better communication and cooperation among participants. This enhancement is expected to reduce the likelihood of errors and misunderstandings throughout the construction process. VR technology can be used in construction to reduce the risks of exceeding budget and schedule by improving communication amongst experts. Time overruns in construction projects are predominantly attributable to inadequate communication and management among personnel and stakeholders. This results in project delays and heightened costs, as expenditures typically escalate with the project's duration.

Furthermore, the use of VR and BIM improves internal and external communication in the AEC industry. Integrating VR demonstrations for BIM

models in construction projects could radically transform the industry by altering the methods of collaboration and interaction among professionals. Through VR technology, users acquire a concrete comprehension of the BIM model, facilitating the elucidation of project structures and reducing ambiguity. Moreover, project managers can utilise this integrated technology to supervise building progress remotely without needing on-site physical presence.

Integrating VR with BIM has a profound and revolutionary effect on the construction industry. It enables immersive experiences and facilitates remote collaboration. It facilitates the creation of visual representations at a 1:1 scale, making decision-making processes more efficient for all parties involved. This integration optimises project management processes and enhances overall project efficiency by providing a virtual tour of the construction site prior to initiation. This optimises project planning and construction sequencing, reducing delays and increasing productivity, hence enhancing project timelines.

Other than that, integrating BIM models into a VR environment enables construction workers and facilities managers to undergo training through very realistic simulations of the actual building or infrastructure. These simulations replicate real-world conditions, including layout, materials, and systems, enabling workers rehearse operations such as assembly, installation, or maintenance without requiring on-site presence. This enables workers to interact with the virtual world to execute jobs, acquire procedures, and acclimatise themselves to the construction site in a hazard-free setting. This

enhances their comprehension of the project mitigate errors when they commence real-world tasks.

Additionally, employing BIM models in VR enables safety teams to visualise dangerous regions on-site, including high-risk zones, heavy equipment operating areas, and locations with fall dangers. Workers can be trained to manage these risks in a virtual setting, thereby equipping them for real-life challenges. VR simulations enable project managers to beforehand assess and confirm safety protocols. This ensure that safety standards are pragmatic, effective, and comprehensively understood by the workforce. Immersive safety training sessions utilising BIM data enhance workers' comprehension of the site and associated hazards, resulting in safer conduct and a reduction in accidents on the building site.

However, the need for more proficiency and financial resources has impeded the extensive use of BIM in Malaysia, namely within the private building sector. Despite the significant potential of VR technology in the construction industry, its implementation has yet to keep up with BIM. Simultaneously deploying both technologies in Malaysia may cause issues in this case. In order to guarantee the effective implementation of these technologies, it is crucial to augment the knowledge and comprehension of BIM and VR among construction experts and workers in the country.

The primary hurdle to integrating these technologies stems from a restricted comprehension and recognition of their advantages to the construction sector.

Although the Malaysian government implemented BIM in 2007, this technology still requires extensive acceptance within the industry, specifically among private-sector contractors. Furthermore, the requirement for additional expertise in the construction industry, combined with the restricted distribution and application of these technologies, presents difficulties in transferring knowledge. The intricacy is exacerbated by inadequate financial resources to incorporate new technology into a corporation, necessitating a significant investment. Furthermore, it is crucial to undergo training to acquire thorough comprehension and expertise in these technologies.

The gradual advancement of BIM in Malaysia presents a significant obstacle to the adoption of newly integrated technologies, including extended reality technologies such as virtual and augmented reality. In order to effectively incorporate these developing technologies into the construction industry in Malaysia, it is imperative to carry out a comprehensive study to establish trust among contractors in Malaysia, hence motivating them to implement and use these technologies inside their businesses. It is recommended that a future study be conducted to evaluate the understanding and proficiency of contractors in Malaysia about the integration of BIM and VR technologies.

Moreover, numerous research studies indicate that the integration of BIM with VR offers advantages to the AEC industry. It enables the remote monitoring of building sites and promotes greater collaboration by facilitating improved communication in a virtual setting. However, these advantages only encompass a small portion of the possible benefits that various technologies

can achieve; extensive study is vital to ascertain the enduring benefits of integrating BIM-VR in the construction sector. Given the widespread recognition of the advantages of this integration among the major stakeholders in the industry, the implementation of BIM and VR integration is expected to be extensive in the Malaysian construction sector.

The amalgamation of VR and presents considerable prospects for the construction sector in Malaysia. This synergy can foster more efficient and sustainable construction methods by strengthening visualisation, improve safety training, and resolving problems in BIM adoption. Embracing VR-BIM integration will be essential for fostering innovation and enhancing project outcomes as the industry evolves.

2.7 Summary of Chapter

Integrating VR with BIM on construction sites can efficiently address several challenges the construction industry encounters, such as communication difficulties, safety management problems, delays, and excessive expenses. These integrated technologies are purposefully intended to tackle and oversee these difficulties. Communication problems can be effectively addressed and reduced by scheduling remote coordination meetings. These tools promote collaboration and communication, hence assisting in team decision-making. Integrating VR with BIM technology promotes communication and problem-solving abilities, enhancing efficiency in interactive and collaborative projects. VR has the potential to influence significantly every phase of the

construction process, starting from the initial planning to the completion. VR enables the evaluation of design options and proposals inside a simulated environment, facilitating the detection and resolution of errors, construction difficulties, and concerns related to functionality before the actual construction process begins. This proactive strategy aids in the prevention of excessive expenses and delays.

However, the integration of VR and BIM may need to be improved due to the increased complexity it brings to the project. This complexity manifests in the need for additional staff training, competence in the technologies utilised, and the implementation of more advanced equipment. The main limitation of using these technologies in the construction sector is the expense, as they require specialised equipment. Therefore, significant financial resources are necessary to successfully carry out this programme within Malaysia's building industry. Therefore, it is prudent to focus on the implementation of these technologies with G7 contractors in Malaysia, given their comparatively greater financial resources available for construction projects than those of other construction companies.

Integrating VR with BIM may face challenges, mainly from the requirement for a deeper understanding of the advantages of both technologies. Nevertheless, many tools and services exist that might assist construction professionals in navigating these challenges. As VR and BIM technology progress and become more accessible, construction professionals are anticipated to integrate these technologies into their companies. VR and BIM in the construction sector offer

significant benefits in addressing on-site construction challenges in Malaysia. The progressive development and widespread accessibility of this technology will undeniably exert a more significant impact on the construction industry. Integrating VR into BIM processes is essential for using the capabilities of this technology entirely in the construction industry. This adoption will effectively address the existing challenges encountered by the Malaysian construction sector.



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter extensively explains the method used in this research. The methodology entails surveying to identify and analyse on-site construction challenges within the Malaysian construction sector. The survey utilises a subject-completed instrument comprising closed-ended and Likert scale inquiries. The complete procedure of assessing the gathered data involves a range of tests, encompassing both descriptive and inferential tests. In addition, Cronbach's Alpha is employed to evaluate the reliability and internal consistency of the questionnaires. The following sections in this chapter will offer a more detailed explanation of these procedural measures.

3.2 Flowchart of Research

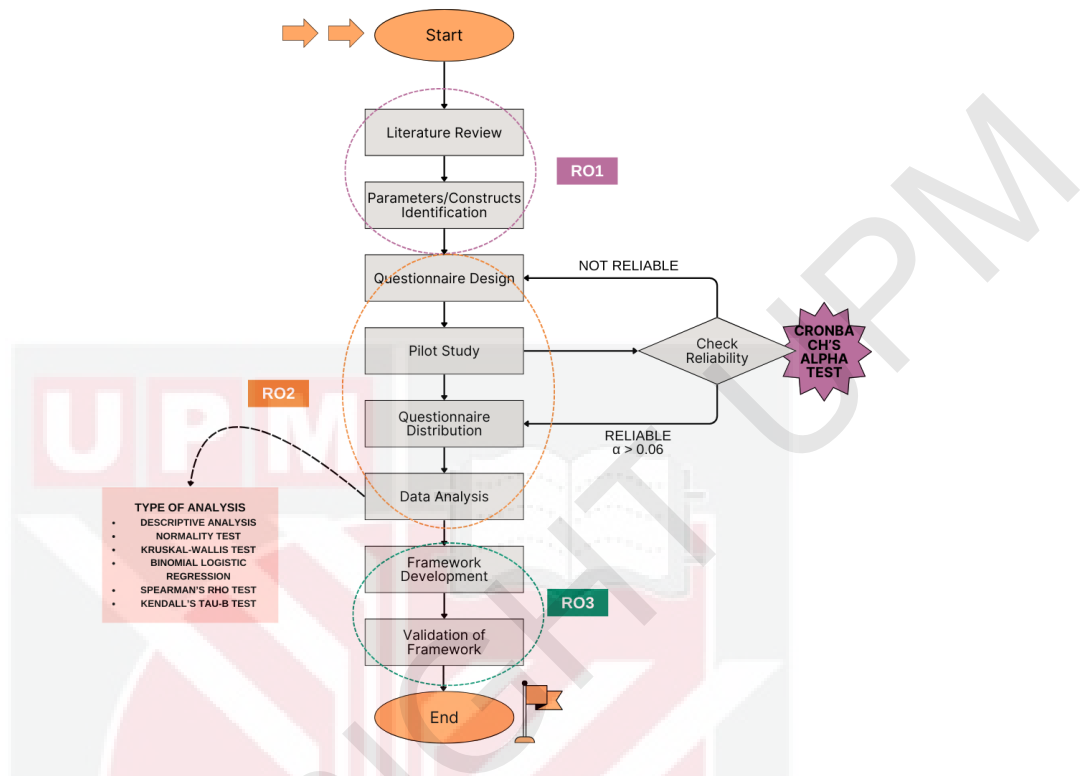


Figure 3.1: Flowchart of Research

As illustrated in Figure 3.1 above, the research begins with a thorough literature evaluation. The main objective of this review is to investigate and determine the criteria or elements that impact on-site construction challenges in Malaysia. Furthermore, the literature evaluation aims to produce a comprehensive research report that explicitly addresses building site problems in Malaysia. As emphasised in the current body of research, the primary on-site challenges are linked to management difficulties and project overruns.

After gathering relevant information from literature, the next stage is to create a questionnaire specifically for G7 contractors in Klang Valley. A pilot study is

conducted to evaluate the questionnaire's reliability, utilising Cronbach's Alpha technique to measure its reliability. After the questionnaire has been determined to be reliable, the next step is to distribute it.

The questionnaire is disseminated to the G7-accredited contractors in the Klang Valley region over roughly four months. After collecting data using the questionnaire, the research moves on to analysing the data. The study includes multiple steps, integrating both descriptive and inferential statistics. Afterwards, a framework is developed and then tested by G7 contractors to verify the accuracy of the data and framework.

3.3 Research Design

This study is descriptive research that uses a non-experimental, cross-sectional design to examine the participants' demographic features. The survey was conducted in 2023 in the Klang Valley. The term "Klang Valley" denotes a metropolitan area in Malaysia encompassing the Federal Territory of Kuala Lumpur and Putrajaya, as well as many districts of Selangor, namely Petaling, Klang, Gombak, Hulu Langat, Sepang, and Kuala Langat. The emphasis was placed on contractors classified as G7 firms, as they had significant financial resources and were more likely to embrace innovative technology inside their organisations.

The survey design is meticulously structured to capture essential indicators that represent the main issues in the construction sector. The strategy

selection is based on thorough literature that identifies cost overrun, time overrun, safety hazards, and communication among stakeholders as the main issues encountered on construction sites. Olanrewaju (2017) states that building issues are primarily caused by inadequate communication among project stakeholders.

The selected characteristics reflect the real-world observations outlined in academic literature, addressing the industry's critical issues. The survey aims to understand the multifaceted problems on construction sites by examining how common these elements are and how they affect the project's outcome.

The assessment considers safety hazards as a crucial factor due to the acknowledgement that the building sector in Malaysia is among the most dangerous. As noted by Asan and Akasah (2015), the construction industry in Malaysia experiences a high rate of disability and fatalities among on-site workers, making safety a significant concern.

The research design strategically aligns with the literature by carefully selecting survey characteristics to capture the issues faced by the construction industry in Malaysia. This connection guarantees that the study is grounded in empirical evidence, enabling it to provide insights relevant to the industry's multifaceted realities.

3.3.1 Constructs

In this specific instance, the management context entails the recognition of two fundamental concepts: "Control Measures" and "Management Problems." These constructs are specifically created to tackle different aspects of the management context. "Control Measures" is designed to address concerns about resolving diverse situations. The CM construct focuses on devising strategies and implementing methods to address and minimise issues that may occur during the management of construction projects.

On the other hand, "Management Problems" refers to the challenges encountered by managers in the construction sector. This concept explores the difficulties, barriers, or intricacies that managers may face during the planning, execution, and control stages of construction projects. It offers a structure for comprehending and classifying the challenges that may occur in the administrative parts of construction management.

When considering the overrun context, two further elements become apparent: "Overrun Problems" and "Overrun Effects." These structures are essential for gaining a complete grasp of the difficulties related to cost and time overruns in building projects. "Overrun Problems" primarily focuses on challenges within the construction sector that are directly associated with project overruns. This construct facilitates identifying and categorising the fundamental reasons and underlying elements contributing to excessive costs and delays.

Other than that, “Overrun Effects” broaden the viewpoint to consider the outcomes or repercussions of cost and time overruns in the construction sector. This construct illuminates the broader ramifications, consequences, or impacts of pervasive difficulties on several facets of construction projects and the industry.

Overall, the development of these constructs offers a methodical structure for examining and classifying problems in management and overrun. By distinguishing between control measures and issues in the management domain, as well as between issues and consequences in the context of project overruns, this method allows for a more detailed and thorough analysis of obstacles within the construction sector.

3.3.2 Conceptual Research Model

The initial phase of defining the prevailing construction challenges in Malaysia has been outlined in the preceding chapter. This phase is grounded on a conceptual model encompassing four distinct categories, as established by this research. Hence, these four elements influence the adoption process of BIM and VR in Malaysia, necessitating empirical testing of their linkages. The image below presents a hypothetical model demonstrating the correlation of these factors.

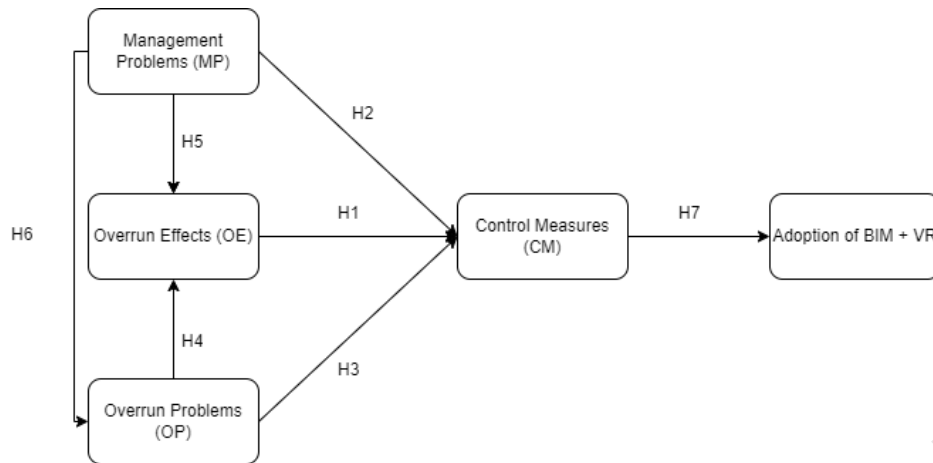


Figure 3.2: Conceptual model of the research

The hypotheses of this research are as follows:

- H1: Overrun effects can be solved with control measures.
- H2: Management problems can be solved with control measures.
- H3: Overrun problems can be solved with control measures.
- H4: Overrun problems lead to overrun effects.
- H5: Management problems lead to overrun effects.
- H6: Management problems lead to overrun problems.
- H7: One of the control measures is the adoption of the integration of BIM and VR technology.

Through a comprehensive analysis of existing literature, it has been established that there are noteworthy correlations between various variables.

These variables include the effects of exceeding budgets and the measures taken to control them (H1), the challenges faced in project management and the corresponding control measures (H2), the issue of exceeding budgets and the measures taken to address it (H3), the combined impact of exceeding

budgets and project management challenges on the effects of exceeding budgets (H4, H5), and the interplay between project management challenges and the issue of exceeding budgets (H6). H7 demonstrates that implementing BIM and VR are effective control techniques in the construction industry.

3.4 Research Instruments

The study employed subject-completed instruments, including closed-ended and Likert scale questionnaires the respondents completed. Participants were engaged using both their corporate email accounts and personal email addresses. The questionnaire was initially designed online using Google Forms. The URL to the forms was then shared via email with the intended recipients. In addition, an alternative approach entailed utilising mobile platforms such as LinkedIn, Facebook, and WhatsApp to disseminate the questionnaire, providing more accessible accessibility.

3.5 Questionnaire Development

A questionnaire is a systematic research tool comprising a sequence of written questions intended to collect data from participants. The design and implementation of questionnaires are essential for assuring the reliability and validity of the collected data, which ultimately affects the quality of the study findings. The principal objective of a questionnaire is to gather pertinent information from a designated population, which can be accomplished through

many forms, including self-administered or interviewer-administered surveys (Reis et al., 2016; Christley, 2016).

A structured self-administered survey was created in English and Malay, consisting of 21 inquiries. The questionnaire was divided into three sections. The first section gathered background information, while the second and third sections addressed on- site construction difficulties and general questions regarding project management. Section C employs dichotomous categorical questions, offering only "Yes" and "No" as response alternatives. In contrast, Section B utilises 5-point Likert scale questions. Li (2013) utilised a 5-point Likert scale, a commonly used psychometric scale in quantitative research, to assess responses. This assessment aims to evaluate an individual's attitude and viewpoint regarding a particular set of statements. When creating a Likert scale, constructing the items is critical to ensure that the instrument produces accurate and valid values when added together. The following table displays the allocation of numerical scores for the Likert scale.

Table 3.1: Assignment of Likert scale's numerical scores

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

(Source: Likert, 1932)

The questionnaire is divided into several constructs, namely the management construct and the overrun construct. In the management context, inquiries focus on on-site management concerns and solutions. On the other hand, the overrun construct deals with questions regarding both overrun problems and their impact on the construction sector in Malaysia. The questions were designed based on these constructs and the responses to the questions in these two dimensions were measured using a five-point Likert scale. The following table displays the questions and their corresponding constructs as labelled in the surveys.

Table 3.2: Questionnaire for Management and Overrun constructs

No	Question	Reference	Constructs	Code
1	A well-trained construction worker is compulsory in every project	Mohd Fateh et al., 2022	Management	CM1
2	The most prevalent issues in the construction industry are time delays and cost overrun	Aziz & Hafez, 2013; Koushiki et al., 2005	Overrun	OP1
3	Delays in construction can be defined as a loss of efficiency and productivity	Sanni-Anibire et al., 2020	Overrun	OP2
4	Delays in construction have negative impacts in terms of cost	AlSeaimi et al., 2013; Azhar & Choudhry, 2016	Overrun	OE1
5	Most construction projects end up costing more and taking longer than expected	Garemo et al., 2015	Overrun	OP3
6	Most project experience cost and time overrun because of poor management	Sambasivan & Soon, 2007; Flyvbjerg et al., 2002	Overrun	OE2
7	Monitoring the progression of workflow and sequence are important to save cost and time.	Shrivas & Singla, 2020; Patil, 2017	Overrun/ Management	OE3

Table 3.2: Continued

8	Construction workers are more likely to be injured and can lead to death than other workers	Sousa & Teixeira, 2004	Management	MP1
9	Risk-free workplace is essential for increasing output, efficiency and quality	Farooqui et al., 2008	Management	CM2
10	Proper safety measures can help reduce the risk of accidents and injuries	Malekitabar et al., 2006; Ning et al., 2018	Management	CM3
11	Communication is essential in all stages of construction	Mohammed et al., 2016	Management	CM4
12	Poor communication among construction parties has an impact on the main project components	Gebken & Gibson, 2006	Management	MP2
13	Reworks are frequently performed as a result of poor communication	Dainty et al., 2006; Tipili et al., 2014; Love & Li, 2000; Sambasivan & Soon, 2007	Management	MP3
14	Regular meetings and communication can help stakeholders collaborate to resolve issues	Fichet & Giraud, 2007	Management	CM5

Table 3.2 demonstrates that unique codes were allocated to each question according to their corresponding components. In the context of management, the abbreviation "CM" was employed to denote control measures, whereas "MP" was used to indicate management problems. Within the context of the constructs, the abbreviation "OE" indicated the presence of overrun effects, whilst "OP" signified the occurrence of overrun problems. Properly assigning these codes to questions is essential for distinguishing them and establishing connections between the concepts. The table below shows the explanation of each construct.

3.6 Population and Sample

The population in the Klang Valley area comprised 3,809 G7 contractors. These contractors were explicitly chosen from the pool of registered companies holding a grade seven (G7) licence, which signifies their ability to participate in limitless tendering. They are classified as building construction under the sub-category of B04 – Building Construction Works and/or CE21 – Civil Engineering Works. These two sub-categories encompass residential and non-residential buildings and extensive civil engineering projects such as major public infrastructure, dams, bridges, highways, water and wastewater systems, and utility distribution. Data regarding these contractors was collected from the website.

The study's sample size was 67 respondents ($N = 67$), determined using a 90% confidence interval and a 10% margin of error. Calculating a 90%

confidence interval for a population size of 3,809 is appropriate. This calculation can provide significant insights into the likely range in which the true population parameter is located. Based on previous investigations, sample sizes ranging from 30 to 500 are suitable for most research (Unite For Sight, 2015). Bihu (2021) highlights that in the field of survey methods, a sample can accurately depict the attributes of a specific population when it is appropriately representative. Nevertheless, McCluskey and Topping (2011) argue that the impact of electronic surveys on response rates and representativeness remains uncertain despite their potential cost-effectiveness.

The sample size was calculate using the Equation (1) as follows (Raosoft, n.d.):

$$n = \frac{N}{(1+Ne^2)} \dots\dots(1)$$

Where N is the population size and e is the margin of error.

3.6.1 Sampling Method

The selected sample design for this study is non-probability sampling. Non-probability sampling is a sample selection strategy that employs non-randomized approaches to select a group of individuals for study participation. Probability sampling methods use random techniques to pick samples, ensuring that all population members have an equal chance of being included in the study. In contrast, non-probability sampling does not guarantee equal representation of all population members (Showkat & Parveen, 2017). Non-probability sampling encompasses five distinct sampling methods: convenience sampling, quota sampling, self-selection sampling, snowball

sampling, and purposive sampling. This study used convenience sampling, primarily due to geographical limitations, explicitly focusing on G7 contractors in the Klang Valley.

3.7 Voluntary, Anonymity and Confidentiality

The respondents were given self-administered surveys and a clear and easily understandable introduction, encouraging them to participate voluntarily. Participants were expressly notified that their participation in the survey was voluntary, and the data collected would be only utilised for academic purposes. In addition, they were guaranteed that their answers would remain anonymous and handled with confidentiality.

In research ethics protocols, it is standard practice to anonymise participants or organisations when handling private information or sensitive viewpoints. Upholding confidentiality cultivates trust among participants and complies with ethical requirements of privacy and data security in research. Revealing the identities of organisations or participants may compromise the integrity of the research. Participants' concerns about the potential revelation of personal information may lead to a hesitance in providing truthful responses, thereby generating biased data and perhaps skewed research outcomes (Montero-Sieburth, 2020).

Upholding confidentiality is essential for sustaining trust, complying with legal requirements, and protecting the integrity of research results. Researchers must

effectively address these challenges by using rigorous measures to preserve participant data and fostering an environment that promotes open and honest communication. The study focusses on identifying trends and challenges faced by G7 contractors as a whole, rather than examining individual organisations; therefore, revealing specific company names was not essential for achieving the objectives of the study.

3.8 Data Collection Method

Survey research involves collecting data from a sample of individuals by obtaining their responses to a set of questions (Check and Schutt, 2012). This study method allows for the use of various participant recruitment procedures, data gathering methodologies, and instrumentation methods. The primary aim of this survey research was to swiftly collect data that delineates the attributes of a significant population of interest (Ponto, 2015).

The data for this study was collected using an online survey produced using Google Forms, which primarily consisted of self-administered questionnaires. This strategy was selected based on its ease of distribution across the enterprises, given the extensive geographical coverage of the Klang Valley area. Nevertheless, there were benefits to utilising this online survey technique that were more cost-effective and simpler. Furthermore, the participants can respond to these inquiries at their convenience. The process of collecting data involves the following steps:

1. The questionnaire was created using Google Forms, drawing from relevant research and adhering to the appropriate scale for each item.
2. The respondents comprised all Grade 7 (G7) construction companies registered in Klang Valley.
3. Once the respondents were recognised, the online poll was disseminated via email and several social media sites.
4. Suitable analyses were performed once the total number of samples was reached.

3.9 Pilot Study

A pilot study is conducted as the first phase of this research to ascertain the questionnaire's content validity. Numerous computations are involved in determining the sample size for a pilot study. Teare et al. (2014) suggested that the pilot study should have a minimum sample size of 10% of the desired sample size for the main study, as per expert recommendations. Given that the desired sample size is 67 respondents ($N = 67$), the pilot study will be carried out on a subset of 10 respondents from registered G7 construction companies in the Klang Valley.

According to Abdullah et al. (2015), the sufficiency of 10 participants depends on the specific research setting. Arain et al. (2010) emphasise that a minority of pilot studies result in later major investigations, suggesting that the progression from a pilot study to a more extensive study is not guaranteed. This indicates that the main emphasis of a pilot study is not on achieving

statistical significance but on assessing feasibility, acceptance, and gathering preliminary data (Kim, 2016).

A pilot study is a crucial element in research that aims to assess the respondents' comprehension of the item and phrase included in the questionnaire. Consequently, the reliability of each proposition in the questionnaire was verified. If there are any misconceptions or need for understanding regarding the items in the questionnaire, these questions might be modified before distributing the questionnaire for the primary research.

3.9.1 Reliability of Questionnaire

In addition, the data can be subjected to specific analysis to ascertain the suitability and effectiveness of the technique. The conducted analysis is the Cronbach's Alpha test, which serves as a measure of scale reliability. Reliability refers to the extent to which the constructs in the study demonstrate internal consistency. Cronbach's Alpha, as defined by Creswell (2010), is used to measure the degree of dependability of the research instrument. Pallant (2001) asserts that a Cronbach's Alpha value above 0.6 indicates high reliability and an acceptable index (Nunnally & Bernstein, 1994).

Therefore, a test is considered reliable if its Alpha (α) value falls within the range of 0.6 to 0.7, indicating an acceptable level of reliability. A value of 0.8 or higher is considered to indicate an excellent level of reliability. According to

Hair et al. (2016), the significance of reliability analysis can be determined by assessing its strength using the Rule of Thumb presented in Table 3.3.

Table 3.3: Strength of Association Determination

Alpha Coefficient Range	Strength of Association
< 0.6	Poor
0.6 to < 0.7	Moderate
0.7 to < 0.8	Good
0.8 to < 0.9	Very Good
0.9	Excellent

(Source: Hair et al., 2016)

Cronbach's alpha is a statistical measure used to assess a research instrument's internal consistency or reliability that assesses variables (Cortina, 1993). The formula for Cronbach's alpha is expressed as in Equation (2) shown below:

$$\alpha = \frac{Kr}{[1+(K-1)r]} \dots\dots(2)$$

Where K is the number of factors and r is the average correlation among all factors (the mean of the K (K-1)/2 non-redundant correlation coefficients (i.e., the mean of an upper triangular, or lower triangular, correlation matrix).

3.10 Data Analysis

Once data collection is finished, the data is subjected to processing, sorting, and interpretation utilizing various analytical methods to derive conclusions and address the research objectives. The primary examinations conducted for this study encompass descriptive tests, non-parametric testing, and logistic regression. The initial analysis was the descriptive analysis, including the demographic analysis. Next, other non- parametric tests were performed, including the normality test, Kruskal-Wallis test, Kendall's tau-b test, and Spearman's r test. Finally, the regression analysis aims to ascertain the potential utilization of integrating BIM and VR in the construction sector.

3.10.1 Descriptive Statistics

Descriptive analysis involves analysing, summarising, and presenting the results obtained from a dataset from a sample or the complete population. This study used descriptive analysis to examine the demographic profile. Descriptive analysis provides a comprehensive summary of the study's data. This analysis is utilised to provide fundamental information regarding the variables in a dataset and to highlight the potential association between variables.

3.10.2 Normality Test

A normality test assesses if the sample data originates from a population that adheres to a normal distribution. This test is typically conducted to verify if the

data in this research follows a normal distribution. Analytical or graphical methods can assess the normal distribution. The Kolmogorov-Smirnov, Shapiro-Wilk, and Anderson-Darling tests are the most often used analytical techniques for assessing the normal distribution of data. Graphical verification uses either a histogram or a Q-Q plot.

The data's null hypothesis assumes a normal distribution for all the tests mentioned before. The null hypothesis posits that the frequency distribution of the data adheres to a normal distribution. These tests generated a p-value to determine whether to accept or reject the null hypothesis.

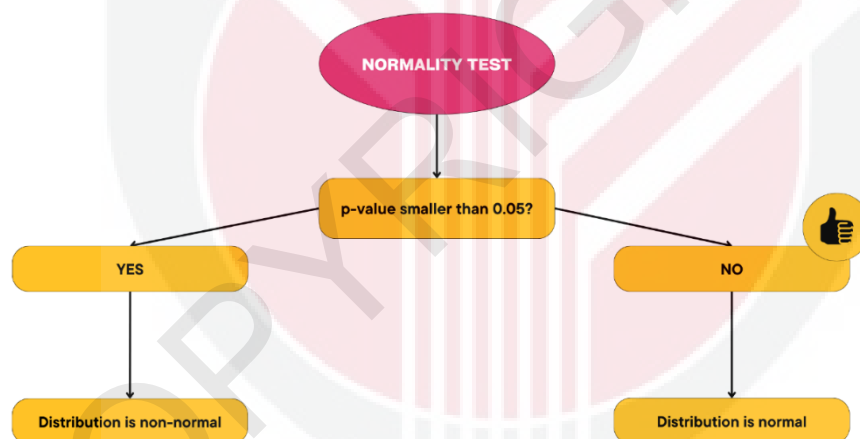


Figure 3.3: Normality Test p-value
(Source: DATAtab Team, 2024)

Based on the depicted representation, a p-value below 0.05 indicates statistical significance. Consequently, it may be inferred that the data does not follow a normal distribution. Typically, a normal distribution is expected to have a p-value over 0.05. However, it is crucial to analyse the graphical solution as this assumption may only be partially correct. When the data deviates from a

normal distribution, it is essential to utilise a non-parametric test rather than ANOVA or the t-test. Non-parametric tests do not presume a normal distribution of the data.

3.10.3 Non-Parametric Tests

A non-parametric test is a statistical analysis procedure that does not make any assumptions about the distribution of the population data based on specific parameters. Consequently, the non-parametric test is frequently termed a distribution-free test. A non-parametric statistical test does not presume that the sampled data follows a normal distribution. Non-parametric tests are employed to assess data when the assumptions underlying parametric tests are not met.

A commonly used approach for establishing the significance value of tests is to establish a significance level, represented as α , which establishes the threshold for determining statistical significance. Typically, a significance level of $\alpha = 0.05$ is commonly employed, suggesting that a p-value below 0.05 is deemed statistically significant (Johnson, 2013). If the p-value is lower than the selected significance level, it indicates that the results are statistically significant, and the null hypothesis can be rejected in favour of the alternative hypothesis (Travers et al., 2017).

3.10.3.1 Kruskal-Wallis Test

The parametric one-way ANOVA test is similar to the non-parametric Kruskal-Wallis test. This test was utilised because it does not necessitate the groups to follow a normal distribution and is less affected by outliers. This test is employed to compare multiple independent and ordinal data groups as this test is a non-parametric assessment grounded in rankings. The objective is to determine if there are statistically significant differences between two or more groups of an independent variable concerning a continuous or ordinal dependent variable. For a proper result in this test, the data must satisfy the four assumptions necessary for a Kruskal-Wallis test.

- Assumption #1: The dependent variable should be measured at the ordinal or continuous level (i.e., interval or ratio).
- Assumption #2: The independent variable should consist of two or more categorical independent groups.
- Assumption #3: It should have independence of observations, which means that there is no relationship between the observations in each group or between the groups themselves.
- Assumption #4: In order to know how to interpret the results the distributions in each group must be determined if they have the same shape.

3.10.3.2 Kendall's tau-b test

Kendall's tau-b (τ_b) correlation coefficient is a non-parametric measure that assesses the strength and direction of the association between two variables measured on an ordinal scale or higher. This test was carried out to determine the correlation between two variables by evaluating statistical associations using the data's ranks. The Tau correlation coefficient yields a numerical value ranging from 0 to 1, with 0 indicating no correlation and 1 indicating a perfect correlation.

To carry out this analysis, the data must satisfy the two assumptions necessary for this test to obtain a valid outcome. The test is based on the following assumptions:

- Assumption #1: Two variables should be measured on an ordinal or continuous scale.
- Assumption #2: Kendall's tau-b determine whether there is a monotonic relationship between the two variables.

3.10.3.3 Spearman's rho test

The Spearman rank-order correlation coefficient is a non-parametric metric that quantifies the magnitude and direction of the relationship between two variables evaluated on an ordinal scale or above. The sign used to represent it is r_s , the Greek letter r . Spearman's rank correlation coefficient serves as a non-parametric alternative to Pearson's product-moment correlation when the

data contravenes one or more assumptions necessary for the latter analysis. This test applies to ordinal variables or continuous data that do not meet the assumptions required for conducting Pearson's product-moment correlation. This test aimed to establish the connection between two variables by analysing statistical associations based on the data's ranks.

In order to obtain a correct result when using Spearman's correlation to analyse the data, the data must satisfy three essential assumptions for Spearman's correlation. The three assumptions are as follows:

- Assumption #1: The two variables should be measured on an ordinal, interval, or ratio scale.
- Assumption #2: The two variables represent paired observations.
- Assumption #3: There is a monotonic relationship between the two variables.

A monotonic relationship occurs when a consistent pattern of both variables increases in value concurrently, or when one variable value increases, the other variable value drops. Below are examples of both monotonic and non-monotonic relationships.

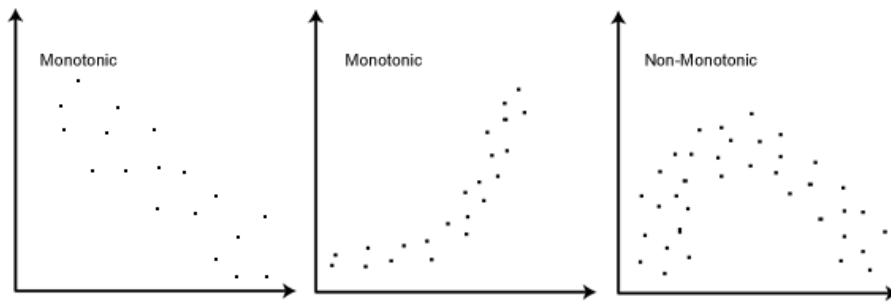


Figure 3.4: Examples of monotonic and non-monotonic relationship
(Source: IndiaFreeNotes, 2020)

3.10.4 Binomial Logistic Regression

Binomial logistic regression, frequently referred to as logistic regression, is a statistical technique employed to assess the probability that an observation is classified into one of two categories of a binary dependent variable. This estimation relies on one or more independent variables, which may be continuous or categorical. This test predicts a dichotomous dependent variable based on one or more continuous or nominal independent variables.

The binomial logistic regression model is a statistical technique that extends the logistic regression model. It is designed for situations where the response variable follows a binomial distribution. It quantifies the likelihood of the dependent variable belonging to a specific category based on the independent variables.

The logistic function, often known as the sigmoid function, converts a linear combination of the independent variables into a probability ranging from 0 to 1. The model can be represented in the Equation (3) below:

$$P(Y = 1) = \frac{1}{1 + e^{-(b_0 + b_1x_1 + b_2x_2 + \dots + b_kx_k)}} \dots\dots(3)$$

Where:

- $P(Y=1)$ is the probability of the dependent variable (Y) being equal to 1
- e is the base of the natural logarithm
- b_0 is the intercept term
- $b_1, b_2, \dots, b_k$ and $X_1, X_2, \dots, X_k$ are the coefficients associates with the independent variables.

The model calculates the coefficients that optimize the likelihood of the observed outcomes based on the predictor variables. Like logistic regression, the binomial logistic regression model produces results commonly described in terms of odds ratios. These odds ratios show the change in the likelihood of the dependent variable being 1 for every one-unit change in the independent variable.

When selecting binomial logistic regression as the analysis method, verifying that the data is suitable for this type of regression analysis is necessary. Binomial logistic regression should only be employed if the data satisfies the necessary assumptions for a valid outcome. The underlying premises are:

- Assumption #1: The dependent variable should be measured on dichotomous scale.
- Assumption #2: Must have one or more independent variables, which can be either continuous, or categorical.

- Assumption #3: The data should have independence of observations and the dependent variable should have mutually exclusive and exhaustive categories.
- Assumption #4: There needs to be a linear relationship between any continuous independent variables and the logit transformation of the dependent variable.

Assumptions #1, #2, and #3 should be checked before assuming #4.

3.11 Development of Framework

The construction challenges of the site framework will be addressed by utilizing the constructs derived from the replies obtained from the questionnaire. The framework encompasses the problems, consequences, and remedies that can be employed for problem-solving to embrace the utilization of BIM and VR. The framework encompasses the challenges that can be addressed by implementing BIM and VR technologies in Malaysia's building industry.

3.11.1 Selection of Experts

Semi-structured interviews were deemed appropriate for gathering ample data, and highly experienced specialists in the construction business were chosen as participants. Experts are deemed qualified based on their expertise derived from their extensive knowledge, skills, experiences, training, or

education. Hence, the subsequent factors were employed to choose the specialist for this investigation:

- Experts on the Malaysian construction sector;
- Familiarity with the prevailing challenges impacting the Malaysian construction industry;
- Proficiency in BIM and VR technologies; and
- Accreditation as G7 contractors in Klang Valley.

3.11.2 Validation of Framework

The validation phase of the framework provided an opportunity to verify the accuracy of the information supporting the draft framework and indicated the crucial aspects for refining the framework. Conceptual frameworks can be validated using expert validation and literature review methods. This study employs an expert validation method by implementing a semi-structured interview.

The interview approach was considered suitable for the validation process due to its capacity to facilitate social and interpersonal interactions. These individuals were part of the previous study survey that focused on the construction problems in Malaysia. There is no specific guideline for determining the number of interviewees and interviews done. However, involving as many interviewees as possible is essential to get the required information.

3.12 Summary of Chapter

The objective of this chapter was to elucidate the research technique, the process of collecting data, and the analysis of the data in the current study. This chapter elucidated the utilization of case studies for collecting data and then expounded on implementing this method in the current research.

Data gathering is merely a single stage within the broader research process. After the data had been gathered, the subsequent phase involved data analysis. The examination of the gathered data will be addressed in the subsequent chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the findings derived from the conducted research, which involved the analysis of responses collected through a disseminated questionnaire that focused on the on-site construction problems in Malaysia. The questionnaire was aimed at Grade 7 (G7) registered contractors in the Klang Valley region. The analysis findings demonstrate the ability to combine VR with BIM to mitigate construction issues in Malaysia. In addition, the study examines the structural link within the established theoretical framework and verifies the formulated hypotheses through testing and validation. This chapter provides a thorough analysis, presentation, and discussion of the data, with an in-depth analysis and explanation of the results.

4.2 Reliability Analysis

Reliability refers to the extent to which the constructs in the study demonstrate internal consistency. The reliability of the construct was evaluated by calculating Cronbach's Alpha (α) coefficient. Cronbach's alpha assesses the internal consistency or reliability of the instrument used to evaluate the research variables (Cortina, 1993).

The general rule of thumb mentioned in Said (2018) is that a Cronbach's Alpha value ranging from 0.6 to 0.8 is acceptable (Wim et al., 2008). Nunally and Bernstein (1994) proposed that a Cronbach's alpha coefficient of 0.7 or above indicates a reasonable level of reliability. Nevertheless, it would be incorrect to believe that a significantly higher alpha value is always good (Taber, 2018). An excessively high alpha indicates redundancy among certain items, as they assess the same question differently.

4.2.1 Reliability Analysis for Pilot Study

The pilot study assessed the questionnaire's reliability, accuracy, comprehensiveness, and viability. It functioned as a means to assess and enhance the survey by determining the dependability and feasibility of the questions. The reliability statistics for the constructs in the pilot study are presented in Table 4.1.

Table 4.1 Reliability Statistics for Constructs

Construct	Number of Items	Alpha (α)
Overrun (Cost and Time)	6	0.756
Management (Safety and Communication)	8	0.610
Overrun and Management (Cost, Time, Safety, and Communication)	14	0.734

The findings suggest that the scales measuring "Overrun in Cost and Time" consisting of six items ($\alpha = 0.756$) and "Management in Safety and Communication" consisting of eight items ($\alpha = 0.610$) were considered satisfactory, particularly considering that the number of items is less than ten. When the "Overrun and Management" construct is combined with 14 elements, it has a dependable value of ($\alpha = 0.734$).

4.2.2 Reliability Analysis for Main Study

The reliability test for the main study is conducted to assess the questionnaire's reliability across all constructs. The findings from the reliability analysis of the primary investigation are presented in Table 4.2.

Table 4.2 Reliability Statistics for Constructs

Construct	Number of Items	Alpha (α)
Overrun (Cost and Time)	6	0.820
Management (Safety and Communication)	8	0.840
Overrun and Management (Cost, Time, Safety, and Communication)	14	0.897

A questionnaire is considered credible if the alpha (α) score is greater than 0.7. Nevertheless, constructions containing less than ten questions can still be regarded credible if they have an α value of 0.6. In the primary analysis, the

"Overrun and Management" constructs demonstrate an alpha value of more than 0.7, confirming the dependability of the study and questionnaire. More precisely, the "Overrun" construct has an alpha coefficient of 0.786, while the "Management" construct has an alpha coefficient of 0.877.

4.3 Demographics and Data Overview

This section presents and explains the results of the descriptive analysis using graphs, tables, and charts. Descriptive analysis involves examining data to find patterns and answer queries regarding the characteristics, location, timing, and extent of a particular phenomenon or the world. This method only applies to analysing Part A and Part C of the questionnaire. Part A pertains to the demographic attributes of the participants, while Part C pertains to general inquiries concerning the study.

4.3.1 Demographic Characteristics of Respondents

Demographic statistics refer to the quantitative data describing a population's attributes or modifications. The study visually represents the respondents' demographic information, such as their years of experience and current job position, using a pie chart. The questionnaire-based study of demographic characteristics is presented in Table 4.3 below.

Table 4.3: Demographic Characteristic Analysis

Demographic Characteristics	Frequency
Years of experience:	
< 5 Years	14
5 to 10 Years	22
10 to 20 Years	14
>20 Years	19
Current Job Position:	
Project Director	9
Project Manager	21
Site Engineer	10
Site Supervisor	6
Others	23

Figure 4.1 illustrates four experience categories: less than five years, 5 to 10 years, 10 to 20 years, and over 20 years. Based on the pie chart, 31.9% of the 69 responses, equivalent to 22 individuals, have 5 to 10 years of experience. In addition, there are 14 participants in the categories of less than five years and 10 to 20 years, while 19 participants have 10 to 20 years of experience. This indicates that most responders are engineers who have recently gained experience, with a working tenure ranging from 5 to 10 years.

Years of experience in the industry. (Pengalaman dalam industri.)
69 responses

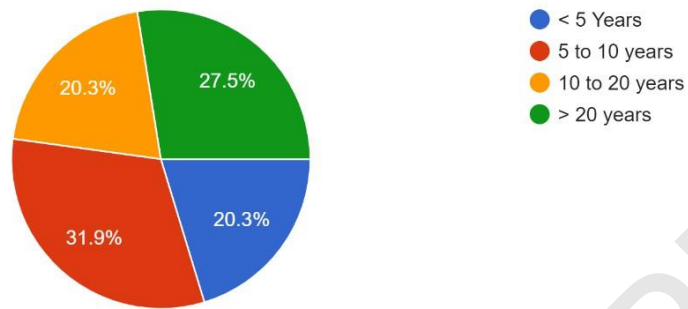


Figure 4.1: Years of Respondents' Experience in the Industry

Table 4.4 below provides the summarised representation of the frequency and percentage of the respondents derived from the information presented in the pie chart from Figure 4.1.

Table 4.4: Years of Respondents' Experience in the Industry

Years of Experience	Frequency	Percentage (%)	Cumulative Percentage (%)
< 5 Years	14	20.3	20.3
5 to 10 Years	22	31.9	52.2
10 to 20 Years	14	20.3	72.5
> 20 Years	19	27.5	100.0
Total	69	100.0	

Figure 4.2 displays the five categories inside the current job position variable: Project Director, Project Manager, Site Engineer, Site Supervisor, and Others. Based on the pie chart, the "Others" category, which includes 33.3% of the total 69 responses, has the highest number of participants, as stated in the

questionnaire. The "Others" category comprises a wide array of professions in the construction business, such as general construction workers, assistant engineers, resident engineers, and several other positions associated with the industry.

Current job position
69 responses

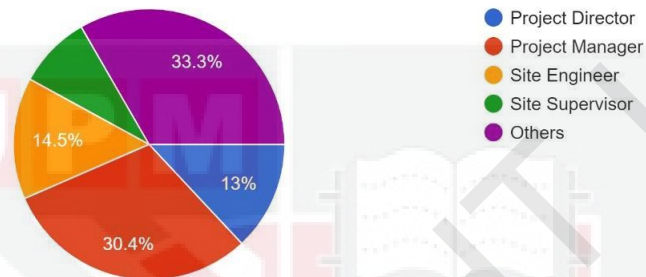


Figure 4.2: Current Job Positions of Respondents

Table 4.5 below represents the frequency and percentage of respondents derived from the information presented in the pie chart from Figure 4.2.

Table 4.5: Current Job Position of Respondents

Job Position	Frequency	Percentage (%)	Cumulative Percentage (%)
Project Director	9	13.0	13.0
Project Manager	21	30.4	43.4
Site Engineer	10	14.5	57.9
Site Supervisor	6	8.7	66.6
Others	23	33.3	100.0
Total	69	100.0	

4.3.2 Descriptive Analysis

This subtopic involves the thorough examination of Part C in the survey. Part C consists of one Likert scale question, assessed from 1 to 5. A rating of 1 indicates "Strongly Disagree", and a rating of 5 indicates "Strongly Agree". In addition, it comprises five Dichotomous questions that require a response of either "Yes" or "No". The initial inquiry in Part C pertains to encountering building complications on the premises, and Figure 4.3 illustrates a graphical representation of the corresponding feedback.

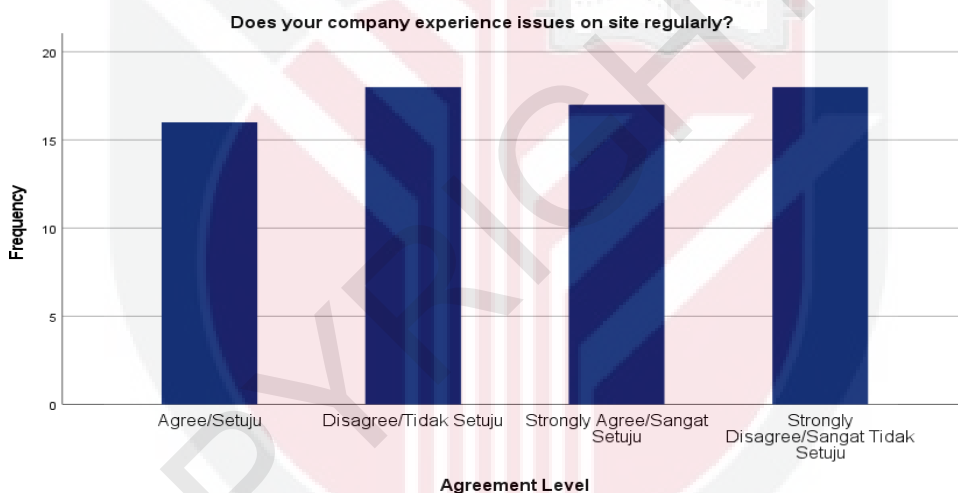


Figure 4.3: Agreement Level on the Issues on Construction Site

The summary of the bar chart in Figure 4.3 is presented in Table 4.6, depicting both the frequency and percentage of the respondents' agreement levels in relation to the given question.

Table 4.6: Agreement Level on the Issues on Construction Site

Agreement Level	Frequency	Percentage	Cumulative Percentage
		(%)	(%)
Strongly Agree	17	24.6	24.6
Agree	16	23.2	47.8
Neither	0	0.0	47.8
Disagree	18	26.1	73.0
Strongly Disagree	18	26.1	100.0
Total	69	100.0	

Figure 4.3 and Table 4.6 demonstrate that the categories of "Disagree" and "Strongly Disagree" have the highest frequencies of agreement, with 18 respondents each. This amounts to 36 individuals expressing disagreement about the regular occurrence of company-related issues on-site, which constitutes 52.2% of the total. This reflects a prevalent belief among G7 construction businesses that they rarely encounter on-site challenges. Conversely, 33 participants agreed on these problems, with 17 strongly concurring and 16 concurring. Significantly, none of the respondents chose "neither" as their response, suggesting a dichotomous distribution where enterprises either frequently experience site troubles or not at all. The bar chart highlights the contrast in experiences, illustrating that some organisations face site troubles while others do not.

Does your company choose the right technique and technology for the optimization of project management? (Adakah syarikat anda memilih tekni... betul untuk pengoptimuman pengurusan projek?)
69 responses

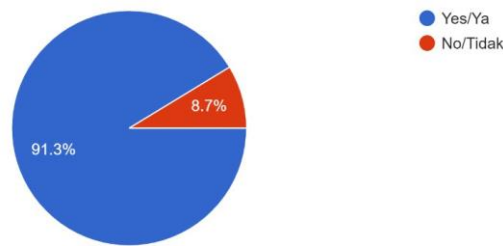


Figure 4.4: Optimisation of the Right Technique and Technology for Project Management

According to Figure 4.4, 91.3% of the participants, namely 63 out of 69, confirmed that their organisations utilise suitable methods and technology for project management. In contrast, 8.7% of participants responded negatively, indicating that their organisations do not utilise appropriate project management approaches and technologies. This indicates a dominant pattern among G7 construction companies in the Klang Valley, where most employ suitable methodologies and technology for efficient project management.

Based on a study by Latiffi et al. (2014), BIM is increasingly utilised by construction professionals in Malaysia. It is predicted to continue growing in the future. BIM is a prominent technology that has acquired popularity in the Malaysian construction industry, highlighting its significance as a widely adopted project management system. The most commonly utilised tools and techniques in project management, as identified by Varajão et al. (2020), are the "kick-off meeting," "progress meetings," "progress reports," "requirements analysis," and "activity list." Thus, it can be deduced that BIM

and traditional project management tools and techniques are widely employed as project management methodologies and technologies in Malaysia.

Will your company consider implementing the usage of new technologies to reduce the construction site issues? (Adakah syarikat anda a...haru untuk mengurangkan isu di tapak pembinaan?)
69 responses

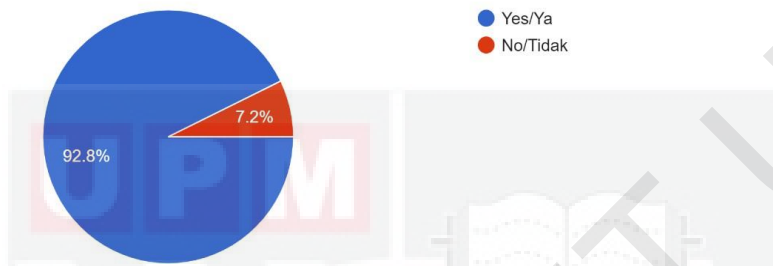


Figure 4.5: Consideration to Implement New Technologies

According to the pie chart in Figure 4.5, a large majority of 92.8% of the companies agree that their organisations will consider using new technology to address construction site problems. Nevertheless, a minority of participants, specifically 7.2%, expressed dissent towards this assertion, equating to 5 responses.

Rauzana et al. (2022) stated that the use of novel and distinctive technology can provide a potential hazard to the execution of a project. Contractors may be inclined to embrace innovative technologies in order to minimise risks and prevent project delays. Zhang and Li-Hong (2022) conducted a study emphasising the crucial variables for contractors to embrace new technologies and execute sustainable building. These factors include implementing policies by governing bodies and effective cost management. These findings indicate

that adherence to laws and cost efficiency are crucial in adopting technology in construction projects.

Do you agree that implementing new technologies can boost construction p
efficiency? (Adakah anda bersetuju pelaksanaka...boleh meningkatkan kecekap
69 responses

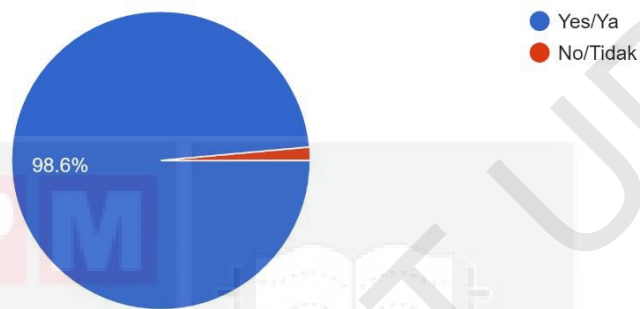


Figure 4.6: Implementation of New Technologies to Boost Construction Efficiency

Based on the statistics displayed in Figure 4.6's pie chart, a significant majority of respondents, totalling 98.6%, recognise that incorporating new technology can improve efficiency in the construction process. Therefore, most G7 construction enterprises agree on enhancing the industry's overall efficiency by embracing new technologies.

Latiffi et al. (2014) suggest that using innovative technologies like BIM can lead to decreased project development time, reduced construction expenses, and enhanced project quality. Moreover, using simulation tools for cost management has been recognised as a valuable strategy to improve the efficiency of construction projects (Alashwal & Chew, 2017).

Do you think the use of alternative reality (example; Virtual Reality, Augmented Reality) could help to reduce the construction issues on site? (Adakah...h membantu mengurangkan isu pembinaan di tapak?
69 responses

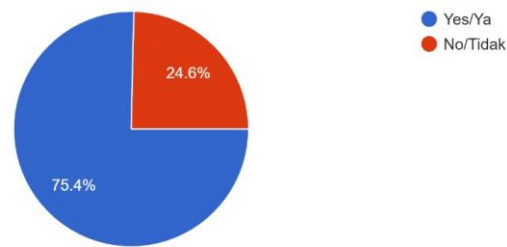


Figure 4.7: The Use of Alternative Reality to Reduce Construction Issues

Based on the data provided in the pie chart shown in Figure 4.7, 75.4% of the respondents agreed that alternative realities such as VR and AR can address on-site construction problems. In contrast, the poll indicates that 17 organisations disagree, as they believe that using alternative reality technologies would not improve their company's efficiency and, as a result, would not effectively address construction concerns on site.

Implementing alternative reality, in addition to other emerging technologies, can mitigate construction challenges and optimise efficiency in construction projects. An investigation conducted by Chai et al. (2019) examines the utilisation of AR in the construction business through the incorporation of BIM content. AR amalgamation with BIM can augment visualisation, coordination, and communication in construction projects, enhancing efficiency and mitigating errors.

Does your company implement Building Information Modelling (BIM) in planning and designing better project management? (Adakah syarikat anda...ereka bentuk pengurusan projek yang lebih baik?)
69 responses

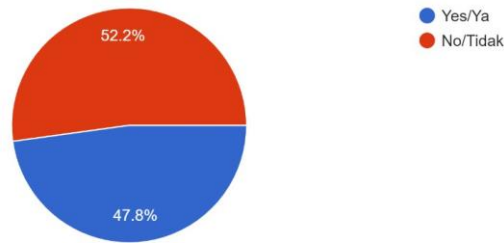


Figure 4.8: Implementation of BIM in Planning and Designing

The adoption of BIM in Malaysia has been slow, as most construction enterprises in the nation have yet to embrace this technology. According to the data in Figure 4.8, 52.2% of the G7 construction businesses in Malaysia admit that they still need to adopt BIM to improve project management by enhancing planning and design.

4.4 Assessment of Data Normality

In order to conduct a normality test, it is necessary to take into account particular assumptions. Khatun (2021) outlines the essential considerations and assumptions for conducting this test, as stated below.

- Assumption #1: Both visual and text analysis outputs must be investigated
- Assumption #2: The Skewness and Kurtosis z-values = -1.96 to +1.96
- Assumption #3: The Shapiro Wilk Test significant value must be more than 0.05 ($p > 0.05$)
- Assumption #4: Histogram and Normal Q-Q Plots visually show that the data are approximately normally distributed.

The normal distribution is a set of probability distributions characterised by a symmetrical bell-shaped curve. The standard normal distribution, often known as the z-distribution, is a normal distribution with a mean of 0 and a standard deviation of 1 (Brereton, 2014). The outcomes of the normalcy assessment are presented in Table 4.7, Table 4.8, Figure 4.9, and Figure 4.10.

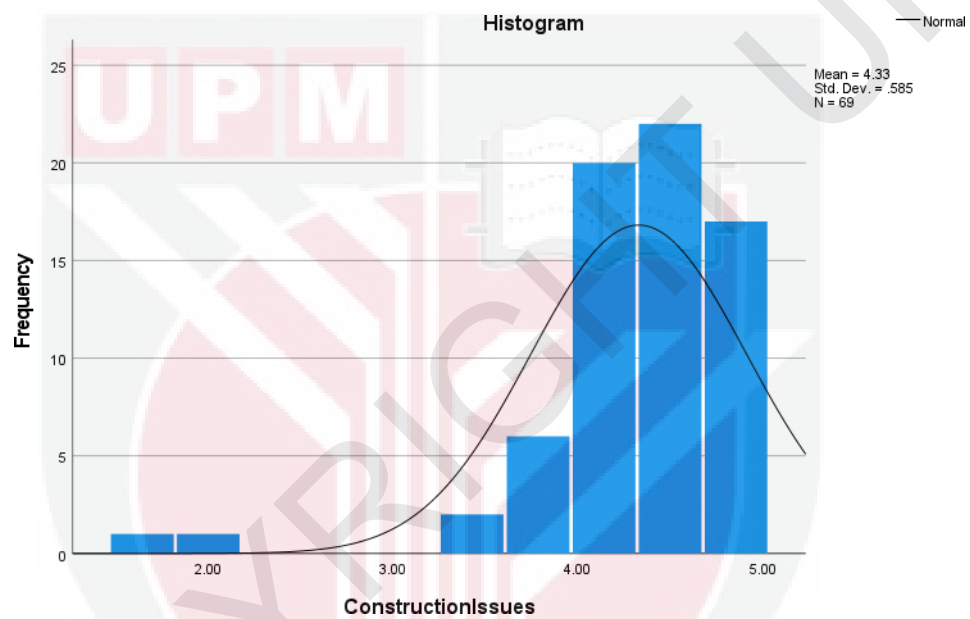
Table 4.7: Descriptive for Normality Test

		Statistics	Std. Error
Construction Issues	Mean	4.3302	0.07037
	95% Confidence Interval for Mean	Lower Bound 4.1898	
		Upper Bound 4.4707	
	5% Trimmed Mean	4.3950	
	Median	4.3571	
	Variance	0.342	
	Std. Deviation	0.58455	
	Minimum	1.64	
	Maximum	5.00	
	Range	3.36	
	Interquartile Range	0.64	
	Skewness	-2.350	0.289
	Kurtosis	8.614	0.570

Table 4.8 Test of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Construction	0.141	69	0.002	0.798	69	0.000
Issues						

a. Lilliefors Significance Correction

**Figure 4.9: Distribution of the Data**

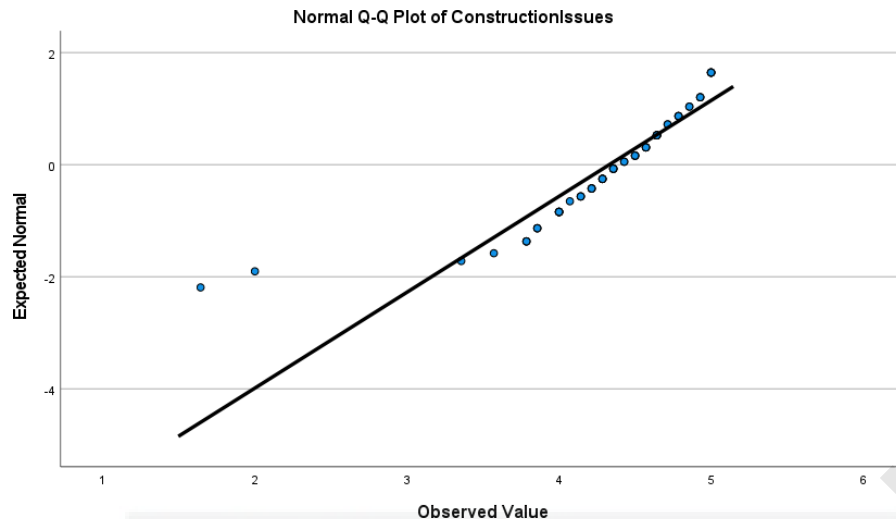


Figure 4.10: Normal Q-Q Plot of the Data

According to the results presented in Tables 4.8 and 4.9, as well as Figures 4.9 and 4.10, it is clear that the data does not conform to a normal distribution. Non-normal distributions exhibit asymmetry, can contain outliers, and may have a more flattened or peaked shape than a standard bell curve (Sainani, 2012). Since the distribution is non-normal, the most suitable statistical test as a replacement for ANOVA is the Kruskal-Wallis test. Hence, using the ANOVA test is inappropriate in this situation due to the requirement of a normally distributed dataset, which needs to be fulfilled by the observed data distribution.

4.5 Kruskal-Wallis Test

The Kruskal-Wallis test serves as a non-parametric substitute for the One-Way ANOVA. The H test is employed when the assumptions underlying ANOVA, such as normality assumptions, are not satisfied. The test employs the H statistic as the test statistic, and the Kruskal-Wallis test determines whether a noteworthy disparity exists among the groups.

Prior to performing the Kruskal-Wallis Test, it is necessary to establish that both the null hypothesis (H_0) and alternative hypothesis (H_a) should be identified. The hypothesis for this specific study was formulated as follows.

- Null hypothesis (H_0): No significant differences exist in the Likert scale responses among the groups or categories.
- Alternative hypothesis (H_a): Significant differences exist in the Likert scale responses among the groups or categories.

Table 4.9 and Table 4.10 show the Kruskal-Wallis Test from the data of the construction issues on-site based on the constructs extracted from SPSS.

Table 4.9: Mean Rank for Kruskal-Wallis Test

	C1	N	Mean Rank
Construction Issues	Strongly Disagree	17	42.97
	Disagree	18	26.08
	Agree	18	27.92
	Strongly Disagree	16	44.53
	Total	69	

Table 4.10: Kruskal-Wallis Test Statistics

	Construction Issues
Kruskal-Wallis H	12.148
df	3
Asymp. Sig.	0.07

In order to reject the alternative hypothesis, this study assumes that the p-value is more than 0.05 ($p > 0.05$). According to Shahabadi and Uplane (2015), a significant p-value indicates a significant difference between the groups under comparison. Given that the asymptotic significance in this study exceeds 0.05 ($\alpha = 0.07$), the null hypotheses are accepted, indicating no statistically significant variations in the Likert scale responses across the groups or categories.

4.6 Binomial Logistic Regression

Binomial logistic regression is a statistical method employed to model the association between a binary dependent variable and one or more independent variables. This statistical analysis aims to establish the correlation between the possible utilisation of VR and the building challenges encountered on-site in Malaysia.

The first step in conducting the binomial logistic regression is by conducting the omnibus test of model coefficients. The Omnibus Test of Model Coefficients is a statistical test that evaluates the overall relevance of a group of predictor variables in the model. The global test assesses the presence of a significant association between the independent variables as a collective and the dependent variable.

The Wald chi-square test is the most commonly used omnibus test in logistic regression. The test relies on the Wald statistic, which quantifies the ratio of

the estimated coefficient to its standard error. A higher Wald statistic indicates more substantial evidence against the null hypothesis of a coefficient being zero.

Table 4.11: Omnibus Test of Model Coefficients

		Chi-Square	df	Sig.
Step 1	Step	13.487	14	0.489
	Block	13.487	14	0.489
	Model	13.487	14	0.489

Table 4.10 demonstrates that the p-value ($p = 0.489$) exceeds the significance level ($\alpha = 0.05$). This indicates that the model does not substantially enhance the data compared to the null model. This may suggest that the predictors provided do not substantially influence the ordinal outcome.

Given that the p-value is higher than alpha in the omnibus test of model coefficients, the null hypothesis cannot be rejected, indicating that the model coefficients lack statistical significance. This scenario can occur for several reasons, including limited sample sizes, significant data variability, or poor correlations between the predictors and the outcome. Highlighted the misconceptions surrounding p-values, emphasising that tiny p-values can occur when the stated test hypothesis is accurate, and significant p-values can occur when the hypothesis is erroneous. It is crucial to assess p-values carefully and consider other aspects like effect sizes and confidence intervals (Greenland et al., 2016).

In addition, the numerical findings were examined, revealing that a high p-value indicates that the sample data provide evidence in favour of the null hypothesis, whilst a low p-value implies otherwise. This is consistent with understanding a situation in which the p-value is greater than alpha for the omnibus test, indicating that the model coefficients lack statistical significance (Wasserstein & Lazar, 2016).

This suggests that the association between the independent variable and the dependent variable, as indicated by the coefficient, is not strong enough to be regarded as a significant or dependable predictor. When a coefficient lacks statistical significance, it indicates that variations in the independent variable linked to that coefficient do not consistently indicate variations in the dependent variable. This indicates the necessity of considering the broader consequences and constraints of exclusively depending on p-values for decision-making in statistical analysis (Wellek, 2017).

Following that, the Hosmer and Lemeshow Test is performed. The Hosmer and Lemeshow Test is a widely used statistical test for evaluating the adequacy of a logistic regression model's fit. The test assesses the degree of agreement between the observed event rates in various groups or bins, which are generated based on projected probabilities, and the expected event rates. The Hosmer-Lemeshow statistics suggest a poor match if the significance value is less than 0.05.

Table 4.12: Hosmer and Lemeshow Test

Step	Chi-Square	df	Sig.
1	5.238	8	0.732

According to the analysis, the model matches the data well because the significance value is more than 0.05. If the test shows a p-value higher than the selected alpha level, often set at 0.05, it implies that the model matches the data. This implies that the observed and projected event rates do not exhibit a significant disparity, suggesting that the model's projections agree with the actual results. Therefore, there is no disparity between the observed and anticipated models in this investigation, so the model's forecasts accurately match the actual results. The specific outcome is presented in Table 4.12 concerning the contingency for the Hosmer and Lemeshow Test.

Table 4.13: Contingency Table for Hosmer and Lemeshow Test

		C5VR = No/Tidak		C5VR = Yes/Ya		Total
		Observed	Expected	Observed	Expected	
Step 1	1	5	4.631	2	2.369	7
	2	2	2.953	5	4.047	7
	3	2	2.637	6	5.363	8
	4	2	1.999	5	5.001	7
	5	2	1.613	5	5.387	7
	6	3	1.230	4	5.770	7
	7	1	0.866	6	6.134	7
	8	0	0.611	7	6.389	7
	9	0	0.385	7	6.615	7

10	0	0.075	5	4.925	7
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The table provided shows no significant difference between the observed and anticipated models, except for the sixth entry. Given that there is just one non-significant value in the Hosmer-Lemeshow test, it does not necessarily indicate a substantial deficiency. Due to the limited sample size, the test findings can be influenced by random fluctuations, which may lead to non-significant results in a few groups solely owing to chance. In addition, the values of observed and predicted are generally equivalent. The model summary of the Binary Logistic regression analysis is presented in Table 4.13.

An intriguing paradox in logistic regression analysis is presented in this work by a situation in which the Hosmer-Lemeshow model fits well. However, the model coefficients are not statistically significant. When the Hosmer-Lemeshow goodness- of-fit test yields a p-value greater than 0.05, it shows that the model's predicted probability agrees with the observed outcomes. Nevertheless, suppose the coefficients of the model lack statistical significance. In that case, it indicates that the individual predictors (independent variables) do not substantially influence the outcome (dependent variable) inside the model.

Certain studies have proposed that the primary criterion should be enhancing the area under the receiver-operating-characteristic curve (AUC). In contrast, others contend that more accurate performance measurements for prediction models are necessary (Pencina et al., 2007). Within the logistic regression

framework, the AUC metric quantifies the model's ability to distinguish between classes. In contrast, the significance of coefficients measures the specific impact of predictors on the model. Thus, a favourable match suggested by the Hosmer-Lemeshow test means that the overall predicted probability closely corresponds to the observed outcomes. In contrast, the absence of statistical significance in coefficients implies that the individual predictors may not be consistently linked to the outcome.

Table 4.14: Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke Square ¹	R
1	63.561 ^a	0.178	0.264	

a. Estimation terminated at iteration number 6 because parameter changed by than less 0.001

The model summary displays the Pseudo R-Square. The often-used metric is the Nagelkerke's R^2 , an adjusted Cox & Snell R-Square version. It adjusts the statistic to encompass the entire range between 0 and 1. Based on the Nagelkerke's R^2 , it can be concluded that 26.4% of the variation in the criterion variable can be attributed to the predictor variables in the model.

Table 4.15: Classification Table

		Predicted			
		C5VR			
Observed		No/Tidak	Yes/Ya	Percentage	
		Correct			
Step	C5VR	No/Tidak	5	12	29.4
1		Yes/Ya	2	90	96.2
Overall Percentage		79.7			

a. The cut value is 0.500

The table above displays the percentages in the first two rows, which indicate the Specificity and Sensitivity of the model in predicting group membership on the dependent variable. Specificity, also known as the True Negative Rate, is the proportion of cases correctly classified as belonging to the non-target or reference group. The precision of this model is 29.4%.

Sensitivity, also known as the True Positive Rate, is the proportion of cases in the target group ($Y=1$), such as those who would select Yes; the model accurately predicted that belong to that group. The model's sensitivity is 96.2%. The overall accuracy rate was excellent, reaching 79.7%. The model demonstrates strong sensitivity as it accurately predicted that 96.2% of individuals who preferred Yes over No would choose Yes. Ultimately, individuals who have encountered site difficulties concur that utilising VR can potentially mitigate the site concerns prevalent in the construction sector.

Binomial logistic regression study identifies the primary predictors of VR-BIM adoption among G7 contractors in Malaysia. The findings demonstrate that factors such as company size, financial resources, and knowledge with VR-BIM substantially influence contractors' adoption of this technology. Considering that knowledge substantially affects acceptability, targeted advertisements and educational programs can improve VR-BIM adoption rates. Furthermore, larger companies exhibit a greater tendency to embrace VR-BIM, suggesting that early adoption strategies may focus on these organisations, as evidenced by this research, thereby creating industry benchmarks for success. This study outlines a strategy for promoting VR-BIM technology in Malaysia, highlighting the essential attributes that may enhance its adoption and empowering industry stakeholders to make informed decisions.

4.7 Non-Parametric Test

Non-parametric tests are statistical methods that are not dependent on a particular distribution for the data. In contrast to parametric tests, which often presume a normal distribution of data and depend on specific parameters (such as means and variances), non-parametric tests offer greater flexibility and can be applied to data that may not conform to these assumptions.

These tests are often used when:

- Data is ordinal: The data can be ranked although may lack significant interval differences.

- Sample sizes are limited: Limited sample sizes may fail to yield a dependable estimation of the population distributions.
- Data does not meet assumptions: The data may be skewed or contain outliers contravene the assumptions of parametric tests.

4.7.1 Correlation between Constructs

In order to carry out these analyses, the hypotheses concerning the Control Measures (CM) items will be associated with new dependent variables, namely Overrun Effects (OE), Control Measures (CM), and Overrun Problems (OP). Two non-parametric tests, Kendall's τ_b test, and Spearman r_s test, were used to compute correlations between an independent variable and dependent variables.

Kendall's tau-b (τ_b) correlation coefficient serves as a non-parametric measure that assesses both the strength and direction of the association between two variables that are measured on an ordinal scale or higher. The Spearman rank-order correlation coefficient serves as a non-parametric measure that assesses both the strength and direction of the association between two variables that are measured on an ordinal scale or higher. The test is relevant for ordinal variables or continuous data that fail to satisfy the assumptions necessary for Pearson's product-moment correlation.

Symbolically, Spearman's rank correlation coefficient is denoted by r_s . It is given by the Equation (4) below.

$$r_s = \frac{1 - (h \sum d_i^2)}{n(n^2 - 1)} \quad \dots\dots(4)$$

Where d_i represents the difference in the ranks given to the values of the variable for each item of the particular data.

Frequently, these two measures closely coincide and result in the same conclusions. Nevertheless, Spearman's ρ is widely used in practical applications and exhibits more sensitivity to errors and inconsistencies in the data when compared to Kendall's tau. The test hypotheses are displayed in the table below.

Table 4.16: Hypotheses for two parametric tests

Test	Null Hypothesis	Alternative Hypothesis	Significant p-value
Kendall's tau-b	CM is not	CM is	< 0.05
Spearman's	associated with	associated with	
rho	OP, OE, MP	OP, OE, MP	

Statistical significance refers to the condition when the p-value of a statistical test is sufficiently low to reject the null hypothesis. The prevailing criterion is typically set at a significance level of $p < 0.05$. The p-value indicates whether the null hypothesis is supported or not. The degree of statistical significance typically fluctuates according to the chosen significance level. In this study, the p-value threshold is set at $p < 0.05$. Therefore, if the obtained significance value is less than 0.05, the null hypothesis will be rejected.

The coefficient correlation is a numerical value from -1 to 1. It functions as a comprehensive indicator of the relationship's strength between the variables. The sign of the coefficient indicates whether the variable changes in the same or opposing direction. A positive value signifies that the variable changes in the same direction, while a negative value indicates that they change in different directions. The table below is a guideline that serves as a general reference for interpreting the strength of a correlation based on the value of the correlation coefficient.

Table 4.17: Coefficient Correlation Value

Coefficient Correlation	Indicator	Sign
Value Range		
-1.0	Perfect	Negative
-0.8 to -1.0	Very Strong	
-0.6 to -0.8	Strong	
-0.4 to -0.6	Moderate	
-0.2 to -0.4	Weak	
0 to -0.2	None	
0 to 0.2		Zero
0.2 to 0.4	Weak	
0.4 to 0.6	Moderate	
0.6 to 0.8	Strong	
0.8 to 1.0	Very Strong	
1.0	Perfect	

(Source: Wayne, 2021)

The Spearman's rank-order test reveals that the derived values exhibit a range of correlations, ranging from weak to strong, and have positive associations with each other. These correlations are statistically significant at a p-value of less than 0.01. The correlation between CM and OE is $r_s = 0.610$, suggesting a strong positive correlation.

On the other hand, the correlation between MP and OP is $r_s = 0.366$, showing a weak positive association. Given that the obtained values were positive, it indicates a simultaneous increase in the correlations among all variables. Therefore, the null hypothesis is refuted, and the alternative hypothesis is accepted due to the data's statistical significance. The table below summarises the association between all variables for Spearman's rho test.

Table 4.18: Association between variables for Spearman's rho test

			CM	MP	OE	OP
Spearman's rho	CM	Coefficient correlation	1.000	0.555	0.610	0.376
		Sig. (2-tailed)	.	<0.001	<0.001	0.001
	MP	Coefficient correlation	0.555	1.000	0.514	0.366
		Sig. (2-tailed)	<0.001	.	<0.001	0.002
	OE	Coefficient correlation	0.610	0.514	1.000	0.477
		Sig. (2-tailed)	<0.001	<0.001	.	<0.001

OP	Coefficient	0.376	0.366	0.477	1.000
	correlation				
	Sig. (2-tailed)	<0.001	0.002	<0.001	.

Kendall's τ_b tests indicate that the correlation values range from weak to strong, demonstrating a positive correlation between the independent and dependent variables. Nevertheless, the correlation between MP and OP is notably low, with a τ_b value of 0.288. This indicates a weak association and essentially no relationship between these two variables as the value approaches zero. All values have been statistically verified to be significant, with a p-value of less than 0.05. Therefore, the null hypothesis is refuted, and the alternative hypothesis is accepted due to the statistical significance of all results.

The table below presents a summary of the relationship between all variables for Kendall's tau b test.

Table 4.19: Association between variables for Kendall's tau b test

			CM	MP	OE	OP
Kendall's tau b	CM	Coefficient	1.000	0.449	0.505	0.303
		correlation				
		Sig. (2-tailed)	.	<0.001	<0.001	0.001
	MP	Coefficient	0.449	1.000	0.423	0.288
		correlation				
		Sig. (2-tailed)	<0.001	.	<0.001	0.002

OE	Coefficient	0.505	0.423	1.000	0.396
	correlation				
	Sig. (2-tailed)	<0.001	<0.001	.	<0.001
1					
OP	Coefficient	0.303	0.288	0.396	1.000
	correlation				
	Sig. (2-tailed)	<0.001	0.002	<0.001	.

4.7.2 Association between Overrun Effects and Control Measures

Based on previous subtopic, it can be observed that the OE and CM variables exhibit the strongest correlation with each other. The Spearman's correlation test yielded a correlation coefficient of $r_s = 0.610$, while the Kendall's tau-b test yielded a correlation coefficient of $\tau_b = 0.505$. Both correlations, falling within the range of 0.5 to 0.7, indicate a moderate to high relationship between the variables. Given that Spearman's correlation test typically yields larger values, the correlation between these variables is deemed strong, as the value of r_s falls inside the range of strong coefficients. The following table displays the correlation between the OE and CM constructs using Spearman's rho.

Table 4.20: Association between CM and OE for Spearman's rho test

			Q10	Q11	Q4
Spearman's rho	Q10	Coefficient correlation	1.000	0.604	0.368
		Sig. (2-tailed)	.	<0.001	<0.001
	Q11	Coefficient correlation	0.594	1.000	0.547

	Sig. (2-tailed)	<0.001	.	<0.001
Q4	Coefficient correlation	0.380	0.547	1.000
	Sig. (2-tailed)	<0.001	<0.001	.

Based on the provided table, the strongest association is observed between Q10 and Q11. Given that both Q10 and Q11 fall inside the same construct, namely CM, a significant connection is observed solely between the construct. The strongest link between OE and CM is observed between Q4 and Q11, with a correlation coefficient (r_s) value of 0.547. Given that the p-value is less than 0.001, below the threshold of 0.01, the correlation between the variables is deemed statistically significant.

The following table displays the correlation between questions from the CM and OE constructs, as determined by Kendall's tau-b test.

Table 4.21: Association between CM and OE for Kendall's tau b test

			Q10	Q11	Q4
Kendall's tau b	Q1	Coefficient correlation	1.000	0.594	0.368
	0	Sig. (2-tailed)	.	<0.001	<0.001
	Q1	Coefficient correlation	0.594	1.000	0.547
	1	Sig. (2-tailed)	<0.001	.	<0.001
	Q4	Coefficient correlation	0.368	0.547	1.000
		Sig. (2-tailed)	<0.001	<0.001	.

The table above demonstrates the strongest association between the CM and OE constructs was observed between Q11 and Q4, with a correlation coefficient (τ_b) of 0.537. Kendall's tau-b test consistently yields a slightly lower value than Spearman's rank coefficient, while the correlation between constructs remains statistically significant. Therefore, the null hypothesis is refuted, confirming the presence of a significant association between the constructs.

4.7.3 Construct Relationships and Hypotheses

This study presents the potential correlations among the constructs OE, OP, MP, and CM, along with the statistical results from Spearman's rho and Kendall's tau-b test, as illustrated in the table below.

Table 4.22: Relationship and hypothesis of constructs

Relationship	Hypothesis
OE-MP	Inadequate management methods result in increased overruns.
OP-MP	Management problems are a key driver of overrun problems
OP-OE	As overrun problems increase, the overrun effects tend to increase as well
CM-OE	The application of strong control measures reduces overrun effects
CM-OP	Effective control measures help reduce the likelihood of overrun problems

CM-MP	Proper control measures can alleviate the effects of poor management
--------------	--

The findings for OE-MP reveal a positive correlation, suggesting that as management issues increase, the severity of overrun impacts amplifies. This positive correlation suggests that ineffective management practices, such as poor planning, communication, or decision-making, directly contribute to delays, cost overruns, and other unsatisfactory project results. A positive correlation between management problems (MP) and overrun problems (OP) in OP-MP signifies that an escalation in management difficulties is associated with a rise in operational overruns. Inadequate management directly correlates with challenges such as project rework, missed deadlines, and inefficiencies that lead to heightened project costs. This association highlights the imperative for adept project management to mitigate overrun problems.

A significant positive correlation between CM and OE suggests that effective control measures substantially reduce or mitigate the adverse impacts of overruns. This supports the assertion that implementing robust control measures is essential for managing and mitigating overrun effects, confirming the critical role these measures have in project success. Additionally, CM-MP exhibits a moderate positive correlation, indicating that effective control measures contribute to the resolution of management issues; however, opportunities for enhancement remain. This indicates that control measures may alleviate management issues, although the correlation is weak. This indicates a necessity for additional refinement of management practices or

control mechanisms to improve effectiveness. CM-OP exhibits a low positive correlation, suggesting that control measures have a limited effect on mitigating overrun issues, with the relationship being weak. The weak correlation indicates that control measures must be enhanced, specifically targeting the underlying issues of overruns to achieve more significant effects.

Finally, the moderate positive correlation between OE and OP indicates that overrun issues, including budget and schedule challenges, are moderately associated with the actual impacts of these overruns. This indicates that as the frequency of overrun problems rises, the associated negative impacts also escalate. Therefore, it is crucial to address these issues to manage the resulting effects.

4.8 VR-BIM Framework Development

The initial conceptual model, as presented in Chapter 3, commenced by identifying the most significant challenges in Malaysia's construction sector, drawing upon insights gained from existing literature. The final evaluation divides these concerns into several constructs, including Control Measures (CM), Control Measures (CM), Overrun Effects (OE), and Overrun Problems (OP). The constructs were subsequently examined using two significant correlation coefficient tests: Spearman's rho test and Kendall's tau-b test. The model summary below displays the significant paths indicated by the analysis results.

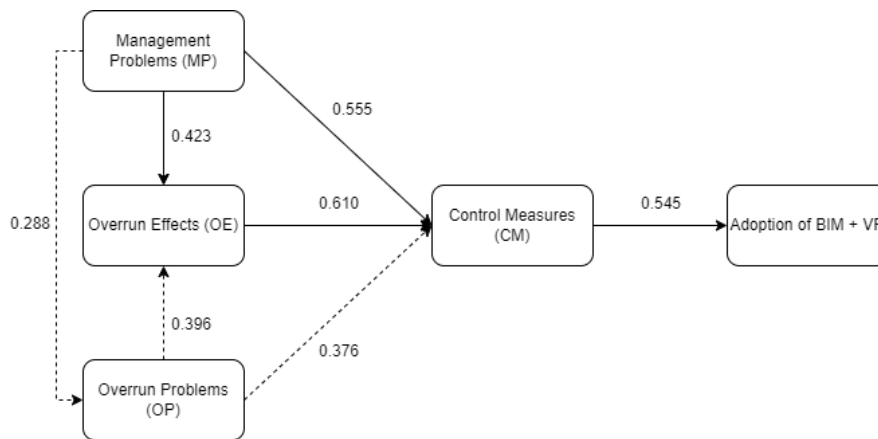


Figure 4.11: Proposed Research Model

The figure above illustrates a link between Management Problems (MP) and Overrun Problems (OP) with a value of 0.288. This indicates a positive correlation between these two codes, while the correlation is relatively small.

The results of Kendall's tau-b and Spearman's rho indicate differing levels of correlation among the constructs, confirming several significant relationships and highlighting potential areas for enhancement. Strong relationships (CM-OE) confirm that control measures significantly mitigate overrun effects. Moderate correlations (MP-OE, OE-OP, CM-MP) indicate the necessity of addressing management and overrun issues through control measures and effective management, though further optimisation is possible. Weaker correlations (CM-OP, MP-OP) imply the presence of additional influencing factors not accounted for, or that these relationships may need improved measures or more thorough investigation.

The correlation between issues of project overrun and management challenges is intricate and multifaceted. Despite the efforts of project

management to mitigate and address various difficulties, cost overruns continue to be a significant concern in project delivery. The causes of cost overruns are many and can be ascribed to variables such as imprecise project planning, unforeseen ground conditions, alterations in design, inadequate cost estimation, and difficulties in material management (Stuchlík, 2018; Sohu et al., 2018; Aljohani, 2017; Abusafiya & Suliman, 2017). These considerations emphasise the complex characteristics of cost overruns and the difficulties they present to project management. Furthermore, the literature highlights the importance of tackling project delays and cost overruns, emphasising the necessity for practitioners to prioritise identifying and mitigating these problems (Le-Hoai et al., 2008). This implies that although project management approaches are designed to tackle different project difficulties, the ongoing occurrence of cost overruns requires a more focused and all-encompassing approach to project management.

Therefore, although project management seeks to tackle different obstacles in project delivery, the continued occurrence of cost overruns highlights the necessity for a more focused and flexible strategy. The complicated nature of cost overruns, caused by faulty planning, material management concerns, and project complexity, requires a thorough and adaptable project management approach to address these challenges adequately.

In addition, as depicted in the previous illustration, there is a slight positive association between the occurrence of overrun problems and the effectiveness of control measures. This underscores the fact that the issues of exceeding the

planned budget and schedule cannot be resolved alone by implementing control measures, namely project management, in the context of this study.

Effective project management is crucial for the success of any project, but it continues to need help resolving issues related to project overruns. The complexities in project management are diverse and can be ascribed to multiple sources. Traditional project management approaches are insufficient to improve the success rate of Enterprise Resource Planning (ERP) projects, specifically in the context of ERP systems (Badewi, 2016). This underscores the constraints of traditional project management approaches in tackling the intricacies of contemporary projects, particularly those encompassing revolutionary organisational transformations.

Furthermore, the growing acknowledgement of project management as a field highlights the changing characteristics of project settings, which might introduce novel and intricate difficulties that conventional project management methods find difficult to tackle (Ballesteros-Sánchez et al., 2019). The transition from project management to programme management is driven by the need to incorporate many functions, projects, and stakeholders to attain the advantages of organisational change. This underscores the changing requirements imposed on project management methodologies (Jiang et al., 2018).

To summarise, the obstacles in project management that lead to overrun problems are many and complex, including constraints in conventional

approaches, insufficient foresight of project expenses, and the dynamic character of project environments. To tackle these issues, adopting a comprehensive and flexible approach to project management that incorporates past experiences, deals with the intricacies of contemporary projects and encourages ongoing learning and enhancement within the field is necessary.

The final model of this research is shown in the figure below.

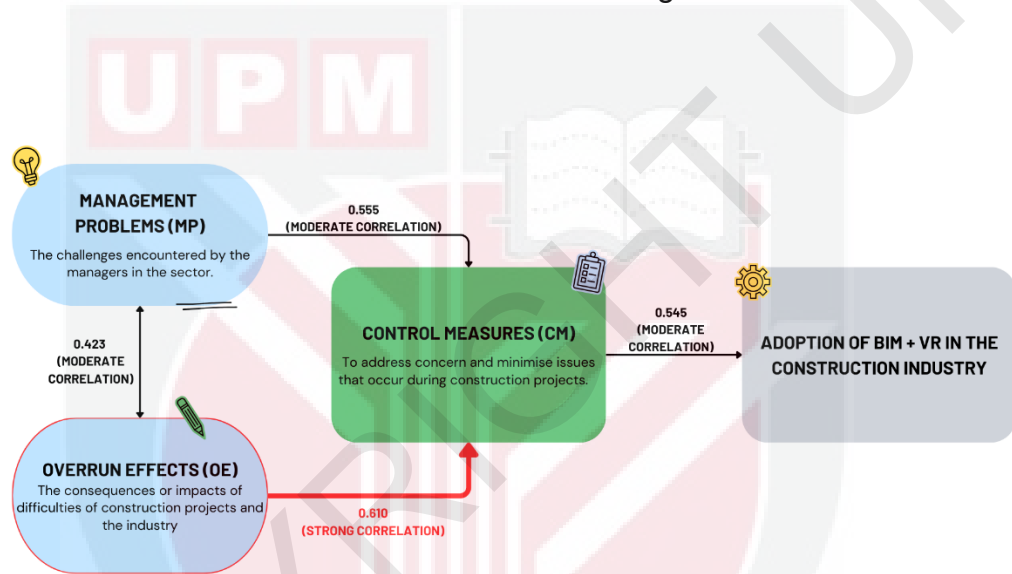


Figure 4.12: Final Research Model

Management Problems (MP) and Overrun Effects (OE) exhibit a moderate positive correlation, as depicted in the figure above. This suggests that an increase in management problems is probable to lead to project overruns in terms of both cost and length. This confirms the model's premise that management concerns directly affect project timetables and budgets. The statistical results provide actual evidence that addressing MP is crucial for reducing OE, hence validating a key hypothesis of this strategy. Ikechukwu et al. (2017) identified various factors contributing to cost overruns, including

issues with finance and payment arrangements, inadequate contract management, material shortages, changes in site conditions, design modifications, errors in contract documents, construction mistakes, price fluctuations, inaccurate estimations, delays, additional work, shortened contract durations, and fraudulent activities. The findings highlight the complex nature of management-related issues that lead to cost overruns in building projects. Juan et al. (2018) indicates that the underestimation of project costs, driven by optimism bias and inadequate designs, is a significant risk factor for cost overruns in public sector projects. This shows that management-related issues are widely acknowledged as factors leading to delays and increased project expenses.

The framework also links OP with the need for effective control mechanisms. The research indicates that CM can reduce OP. Enhanced control procedures lead to a reduction in operational issues within the project. Cost overruns arise from poor management decisions, inadequate financial planning, or inefficiencies across many stages of project management. Pourrostan and Ismail (2012) assert that comprehensive planning, which includes risk assessment and contingency procedures, mitigates potential delays. The links validate the model's assertion that the adoption of effective control methods, particularly the incorporation of VR-BIM technology, immediately alleviates overrun problems. This supports the model's claim that improving project control systems can reduce operational inefficiencies.

The association between CM-MP substantiates the model's assertion that effective control techniques, such as VR-BIM, can alleviate certain management inefficiencies. Real-time visualisation and data management utilising BIM-VR helps mitigate communication failures and inadequate planning, hence reducing their effects on project results. Furthermore, improving communication and collaboration among stakeholders can enhance project coordination and reduce misunderstandings that lead to delays. Control techniques, including improved project planning, financial oversight, and the adoption of technologies such as BIM-VR integration, are highlighted as strategies to mitigate overruns and management challenges.

The adoption of BIM and VR are seen as essential strategies to address management and cost overrun issues as combining BIM with VR can help solve management problems in the construction sector. Combining BIM and VR technologies provides multiple advantages that can help address management challenges in construction projects. The figure above shows a strong positive correlation between Control Measures (CM), one construct of the management construct, and the adoption of BIM + VR. Dixit et al. (2019) explored the merging of facility management with BIM, emphasising the capability of BIM to enhance life cycle management by capturing building data thoroughly and precisely with the collaboration of a facility manager. This suggests that BIM can tackle facility management and operational challenges. Lee et al. (2022) contended that merging of virtual reality with an IFC-BIM model and IoT-based building management systems enhances effective building data management. This connection facilitates centralised data visualisation, allowing

project teams to monitor and control building performance throughout its lifecycle, which is highly beneficial for facility management. Furthermore, it was demonstrated that virtual reality may significantly enhance the coordination process throughout the design phase by allowing stakeholders to identify interferences and conflicts among design systems (Ghobadi & Sepasgozar, 2020). This proactive conflict resolution method minimises delays and cost overruns, leading to more effective project delivery. Ghanem (2022) emphasises the revolutionary potential of VR-BIM in the AEC companies when implemented in construction management.

The potential adoption of integrating BIM and VR in the Malaysian construction sector was evaluated using a methodology that included a survey, coefficient correlation tests, and conversations. The data was obtained via a survey among 69 construction experts from G7 construction companies in the Klang Valley region of Malaysia. The survey's primary objective was to acquire information and expertise from these individuals regarding construction-related matters in Malaysia. The data obtained underwent statistical analysis to identify the salient challenges in Malaysia to facilitate the future adoption of BIM and VR. Based on the analysis, a framework was established to delineate the issues in the Malaysian construction industry and their interconnections.

The final research framework presents a holistic methodology that amalgamates conventional project management practices with modern technologies, such as BIM and VR, to reduce cost overruns and improve project efficiency. The study validated the framework by employing a semi-

structured interview method. The input obtained from the interviews was then utilised to refine the suggested framework.

4.9 Validation of the VR-BIM Framework

Validating a framework requires a thorough and systematic approach to guarantee its credibility and usefulness. The procedure usually includes a combination of different methodologies, validating the framework, adjusting it according to trial outcomes, and utilising expert panels for evaluation and refinement (McMeekin et al., 2020). Expert validation methods, focus group discussions, nominal groups, or video conferencing can be used to validate a conceptual framework.

This study uses the interview approach. Fifteen practitioners with diverse civil engineering backgrounds, including professionals, have been chosen to validate this approach. Before the interview, the predetermined framework was distributed to the interviewees, and the questions were conducted using a semi-structured interview format. The participants' demographic data for this questionnaire is displayed in Table 4.23 below.

Table 4.23: Demographic of the Participants

Participants	Years of Experience	Position
P1	>20 Years	Assistant Engineer
P2	10 to 20 Years	Director
P3	>20 Years	Assistant Engineer
P4	>20 Years	Clerk of Work
P5	5 to 10 Years	Assistant Engineer
P6	<5 Years	Project Engineer
P7	10 to 20 Years	Project Manager
P8	>20 Years	Resident Engineer
P9	5 to 10 Years	Site Supervisor
P10	<5 Years	Engineer
P11	<5 Years	BIM Engineer
P12	<5 Years	QAQC Engineer
P13	10 to 20 Years	Inspector of Works
P14	5 to 10 Years	Assistant Manager
P15	10 to 20 Years	Senior Manager

The summary of participants results for the five questions of the framework evaluation is presented in the table and figure below.

Table 4.24: Classification and Purpose of Questions for Validation

No.	Classification	Purpose
Q1	Effectiveness	Assessing the perceived effectiveness of the framework in addressing construction site issues in Malaysia.
Q2	Applicability	Evaluating the practical suitability of the developed framework for real-world application.
Q3	Clarity	Examining the perceived clarity and comprehensiveness of the framework as a guide for adopting BIM + VR integration in addressing construction site issues.
Q4	Implementation	Assessing the ease of implementing the framework within existing construction companies, with a focus on G7 companies in Klang Valley.
Q5	Potential Impact	Exploring the perceived potential of the framework to mitigate construction site issues in Malaysia.

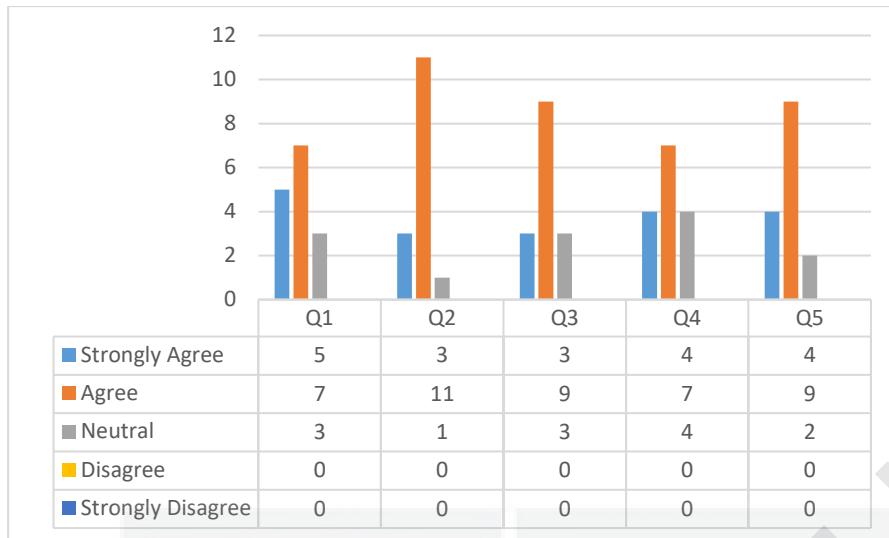


Figure 4.13: Summary of Participants Results

The average mean score was determined from the summary of participants' findings and is displayed in the table below.

Table 4.25: Average Mean Score

	Q1	Q2	Q3	Q4	Q5
Average Mean Score	4.13	4.13	4.00	4.00	4.40

The table displays the average Q1, Q2, Q3, Q4, and Q5 scores as 4.13, 4.13, 4.00, 4.00, and 4.40, respectively. The mean score is commonly utilised to measure central tendency, indicating a dataset's typical or most representative value. This study's average score for all questions is 4 or above, suggesting agreement with the execution of VIR + BM integration. According to the Likert scale, a score of 4 represents 'Agree'.

4.10 Summary of Chapter

This chapter discusses the findings and implications of integrating BIM and VR to address construction site challenges in Malaysia. The chapter commences with a questionnaire aimed at pinpointing the primary and critical concerns in the construction industry. The study targets G7 construction companies in Klang Valley since they have the financial resources to adopt innovative technology to address these concerns. The acquired data was subsequently utilised to determine the feasibility of implementing BIM + VR by creating a study framework. The framework identified that implementing Control Measures (CM) can address primary construction concerns such as Overrun Effects (OE) and Management Problems (MP). Utilising these technologies serves as a method to mitigate these challenges, since the integration of BIM and VR can improve collaboration, design visualisation, and project management. These technologies enable real-time data transmission, assisting in the swift discovery of problems, reducing rework, and enhancing efficiency throughout all project phases.

The statistical analysis strongly endorsed the use of control measures, encompassing improved planning, cost estimation, and technology adoption.

The feedback from G7 contractors further validated the framework, attaining a robust consensus with a mean score of 4.0 for its effectiveness in addressing significant construction issues, including cost and time overruns, as well as improving safety and communication. The validation phase, encompassing expert interviews, confirmed the framework's applicability in real-world

scenarios. Experts agreed that the adoption of BIM and VR technology might significantly enhance project outcomes by optimising management processes, improving decision-making, and addressing the primary challenges of the Malaysian construction industry.

This chapter offers a thorough overview of the primary construction challenges in the Malaysian construction sector and the possible implementation of BIM + VR to address these challenges. The findings of the analysis align with the framework, confirming that the application of CM, incorporating BIM and VR together with improved management strategies, can effectively reduce the overruns and management difficulties commonly encountered in the construction sector. The significant correlations shown in the statistical analyses validate the final framework's effectiveness in reducing cost and time overruns, hence improving overall project efficiency. The results of this study could benefit policymakers, practitioners, and researchers aiming to enhance the construction business in Malaysia.

To enhance the study, the sample size should be augmented by incorporating additional contractors from other regions in Malaysia and possibly from adjacent countries. This would yield a more heterogenous dataset, facilitating a comprehensive knowledge of how VR-BIM integration might resolve building challenges across multiple contexts. An expanded and geographically varied sample would enhance the study's generalisability, aiding in the validation of the framework across varying market situations, project scales, and building methodologies.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The application of virtual reality in the construction sector is increasingly prevalent globally, especially in industrialised nations. Industries in North America, Europe, and certain regions of Asia have progressively used virtual reality with building information modelling to optimise project planning, augment collaboration, and minimise errors during construction phases. The adoption of VR in Malaysia's construction sector remains nascent, with awareness and implementation trailing behind more technologically advanced areas. The principal obstacles found, including elevated costs and technological integration difficulties, are those seen globally but are particularly pronounced in growing markets like as Malaysia.

In advanced markets, the cost-efficiency of VR in construction has been demonstrated consistently, with numerous organisations indicating substantial decreases in rework, material waste, and project delays. The long-term return on investment (ROI) has been advantageous, especially for major building projects that gain from enhanced planning precision and less risk. Globally, the integration of VR with BIM systems has encountered hurdles, especially regarding data interoperability and real-time synchronisation between the two

technologies. Nonetheless, these issues have been predominantly mitigated through technology innovations and the establishment of industry standards, particularly in nations with significant digital revolution in construction. The integration constraints are particularly pronounced in Malaysia, where the requisite technological competence and infrastructure for VR- BIM integration are still in the developmental stage. Contractors have challenges in integrating virtual reality with conventional building information modelling systems, especially in large-scale projects necessitating intricate data management.

The global outlook on VR in construction is favourable, characterised by ongoing technological advancements, decreasing hardware prices, and enhanced software integration. In developed markets, virtual reality is anticipated to become increasingly incorporated into the construction workflow, encompassing design through to post-construction operations. This research indicates that Malaysia has the ability to align with this worldwide trend; nevertheless, increased awareness, investment, and training are essential. The suggested framework for integrating VR with BIM can facilitate the swift adoption of VR technology, enabling Malaysia to align with global leaders in the building sector.

The prospects for VR-BIM in Malaysia are promising, indicating significant potential for disruptive advancements in the building sector. With the decreasing cost of technology, the resolution of talent gaps, and the enhancement of government support, VR-BIM is poised for extensive implementation. This technology will improve project efficiency, collaboration,

and sustainability, enabling Malaysia's construction industry to compete internationally and address the increasing demand for innovation and sustainability in construction.

Based on the survey conducted, survey respondents acknowledged the potential of VR but adoption is constrained by substantial initial expenses and the necessity for advanced technology infrastructure. The integration is promising, yet, it necessitates enhanced awareness and specialist training for the personnel. Although virtual reality has the capacity to substantially diminish costs and time overruns, the primary obstacle to its implementation is the insufficient industry-wide acceptability and comprehension, as the application of VR in Malaysia remains in its nascent phase. By tackling the factors hindering the adoption of VR, the Malaysian construction sector can achieve significant advancements in the integration of VR technologies, by enhancing project outcomes and sustaining global competitiveness.

This study's analyses robustly endorse the notion that the integration of BIM and VR helps resolve critical construction challenges, including management inefficiencies, cost overruns, and delays. Despite hurdles such as substantial initial expenses and technological integration, the prospective long-term advantages render the adoption of BIM-VR technology a worthwhile investment for the building sector. The proposed paradigm for VR-BIM integration acts as a pragmatic guide to addressing these problems and enhancing project outcomes in the Malaysian construction sector and beyond.

This research study successfully met all three research objectives and identified the possibility of adopting BIM + VR technology integration to mitigate construction site concerns in Malaysia. Despite the advantages of this technology for the construction sector, it needs to be more understood, and limitations hinder its adoption in Malaysia.

The main objective is to examine the possible applications of VR technology in Malaysia's construction sector. This objective is accomplished by conducting a comprehensive literature review. Many studies have suggested that VR technology might be integrated due to the growing use of BIM in Malaysia.

The second objective is to pinpoint the main issues that occurred at the construction site in Malaysia. The purpose was accomplished by surveying G7 contractors in the Klang Valley using Google Forms. G7 contractors have greater capital to implement these technologies in their construction projects. The survey revealed that the main problem at the building site is overrun difficulties related to cost and time.

The last objective is to provide a framework for integrating VR with BIM in the building sector. A methodology is created to assess the possible implementation of BIM based on the main challenges encountered at construction sites in Malaysia. This framework was created using the analysis derived from the survey results. The methodology suggests that integrating BIM and VR is feasible in Malaysia to mitigate construction site challenges.

5.2 Recommendations

This section will provide recommendations for future research on integrating VR and BIM in the construction sector in Malaysia.

5.2.1 Recommendation for Future Research

In the context of this study, the majority of the analyses that were carried out were founded on theory, and the sample size for the survey had a significant impact on the results. Because this study has limitations, the next researcher should broaden their sample for future research, concentrating on the building business in Malaysia rather than limiting themselves to the Klang Valley only. In addition, the prospective researcher might also carry out a cost-benefit analysis on implementing BIM and VR in the Malaysian construction industry to assess whether the benefits of using these technologies outweigh the implementation costs.

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APPENDICES

Appendix A

Questionnaire

A1 The Study on The Construction Issues in Malaysia

The Study on The Construction Issues in Malaysia (Kajian Isu-Isu Pembinaan di Malaysia)

Assalamualaikum and a very good day.

The purpose of this research is to achieve the research objectives listed below:

- a) To identify the primary issues that arose at the construction site in Malaysia
- b) To analyse the potential solution for the construction site issues for greater benefits

For this study, I have decided to select among the G7 (grade 7) contractors in Klang Valley to participate in answering this questionnaire.

Your cooperation and help is highly appreciated. Thank you.

Assalamualaikum dan salam sejahtera.

Tujuan kajian ini diadakan adalah untuk memenuhi objektif kajian seperti berikut:

- a) Untuk mengenalpasti masalah utama yang berlaku di tapak pembinaan di Malaysia
- b) Untuk mengkaji potensi penyelesaian bagi isu tapak pembinaan agar dapat memberi faedah yang lebih besar

Untuk kajian ini, saya telah memutuskan untuk memilih antara kontraktor G7 (gred 7) di kawasan Lembah Klang untuk mengambil bahagian dalam menjawab soal selidik ini.

Kerjasama anda semua amatlah dihargai. Terima kasih.

** Indicates required question*

1. I understand the purpose of this research and agree to participate voluntarily. *
- (Saya faham tujuan kajian ini dan bersetuju untuk terlibat secara sukarela)

Mark only one oval.

☐ Yes/Ya

PART A

This part contains 2 questions.

Bahagian ini mengandungi 2 soalan.

2. Years of experience in the industry. *
(Pengalaman dalam industri.)

Mark only one oval.

- ☐ < 5 Years
☐ 5 to 10 years
☐ 10 to 20 years
☐ > 20 years

3. Current job position *

Mark only one oval.

- ☐ Project Director
☐ Project Manager
☐ Site Engineer
☐ Site Supervisor
☐ Others

PART B

This part contains 15 questions. Answer according to the scale as stated below:

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

Bahagian ini mengandungi 15 soalan. Jawab mengikut skala yang ditetapkan di bawah:

- 1- Sangat Tidak Setuju
- 2- Tidak Setuju
- 3- Neutral
- 4- Setuju
- 5- Sangat Setuju

4. A well-trained construction worker is compulsory in every project. *
- (Pekerja binaan yang terlatih adalah wajib dalam setiap projek.)

Mark only one oval.

1 2 3 4 5

Stroi ☐ ☐ ☐ ☐ ☐ Strongly Agree

5. The most prevalent issues in the construction industry are time delays and cost overrun. *
- (Isu yang paling lazim dalam industri pembinaan adalah kelewatan masa dan kos berlebihan daripada yang telah ditetapkan.)

Mark only one oval.

1 2 3 4 5

Stroi ☐ ☐ ☐ ☐ ☐ Strongly Agree

6. Delays in construction can be defined as a loss of efficiency and productivity. *
- (Kelewatan dalam pembinaan boleh ditakrifkan sebagai kehilangan kecekapan dan produktiviti.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

7. Delays in construction have negative impacts in terms of cost. *
- (Kelewatan dalam pembinaan mempunyai kesan negatif dari segi kos.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

8. Most construction projects end up costing more and taking longer than expected. *
- (Kebanyakan projek pembinaan berakhir dengan kos yang lebih tinggi dan mengambil masa lebih lama daripada yang dijangkakan.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

9. Most project experience cost and time overrun because of poor management. *
- (Kebanyakan projek mengalami kos dan masa yang dilampaui kerana pengurusan yang lemah.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

10. Monitoring the progression of workflow and sequence are important to save cost and time. *
- (Memantau perkembangan aliran kerja dan urutan adalah penting untuk menjimatkan kos dan masa.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

11. Construction workers are more likely to be injured and can lead to death than other workers. *
- (Pekerja pembinaan lebih cenderung untuk cedera dan menyebabkan kematian berbanding pekerja lain.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

12. Advanced technology has created a more demanding and hazardous work environment. *
- (Teknologi canggih telah mewujudkan persekitaran kerja yang lebih mencabar dan berbahaya.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

13. Risk-free workplace is essential for increasing output, efficiency and quality. *
- (Tempat kerja bebas risiko adalah penting untuk meningkatkan output, kecekapan dan kualiti.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

14. Proper safety measures can help reduce the risk of accidents and injuries. *
- (Langkah keselamatan yang betul boleh membantu mengurangkan risiko kemalangan dan kecederaan.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

15. Communication is essential in all stages of construction. *
- (Komunikasi adalah penting dalam semua peringkat pembinaan.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

16. Poor communication among construction parties has an impact on the main project components. *

(Komunikasi yang lemah di kalangan pihak pembinaan memberi kesan kepada komponen projek utama.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

17. Reworks are frequently performed as a result of poor communication. *

(Kerja semula sering dilakukan akibat komunikasi yang lemah.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

18. Regular meetings and communication can help stakeholders collaborate to resolve issues. *

(Pertemuan dan komunikasi yang kerap boleh membantu pihak berkepentingan bekerjasama untuk menyelesaikan isu.)

Mark only one oval.

1 2 3 4 5

Strongly ☐ ☐ ☐ ☐ ☐ Strongly Agree

PART C

This part contains 4 questions.

Bahagian ini mengandungi 4 soalan.

19. Does your company experience construction issues on site regularly? *
- (Adakah syarikat anda mengalami masalah pembinaan di tapak dengan kerap?)

Mark only one oval.

- ☐ Yes/Ya
- ☐ No/Tidak

20. Does your company choose the right technique and technology for the optimization of project management? *
- (Adakah syarikat anda memilih teknik dan teknologi yang betul untuk pengoptimuman pengurusan projek?)

Mark only one oval.

- ☐ Yes/Ya
- ☐ No/Tidak

21. Will your company consider implementing the usage of new technologies to reduce the construction site issues? *
- (Adakah syarikat anda akan mempertimbangkan untuk melaksanakan penggunaan teknologi baharu untuk mengurangkan isu di tapak pembinaan?)

Mark only one oval.

- ☐ Yes/Ya
- ☐ No/Tidak

22. Do you agree that implementing new technologies can boost construction process efficiency? *
- (Adakah anda bersetuju melaksanakan teknologi baharu boleh meningkatkan kecekapan proses pembinaan?)

Mark only one oval.

- ☐ Yes/Ya
- ☐ No/Tidak

23. Do you think the use of alternative reality (example; Virtual Reality, Augmented Reality) could help to reduce the construction issues on site? *

(Adakah anda fikir penggunaan realiti alternatif (contoh; Realiti Maya, Realiti Ditambah) boleh membantu mengurangkan isu pembinaan di tapak?)

Mark only one oval.

- ☐ Yes/Ya
☐ No/Tidak

24. Does your company implement Building Information Modelling (BIM) in planning and designing better project management? *

(Adakah syarikat anda melaksanakan Pemodelan Maklumat Bangunan (BIM) dalam merancang dan mereka bentuk pengurusan projek yang lebih baik?)

Mark only one oval.

- ☐ Yes/Ya
☐ No/Tidak

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A2 Proposed Framework Validation

Proposed Framework Validation

Assalamualaikum and a very good day.

Dear Respondents,

Thank you for taking the time to participate in our survey. Your input is incredibly valuable, and we appreciate your willingness to share your thoughts and experiences. This survey aims to validate the proposed framework for the potential implementation of BIM + VR to alleviate construction site problems in Malaysia. Your responses will play a crucial role in helping to reduce the construction issues with the future adoption of these integrating technologies.

Your participation is completely voluntary, and all your responses will be kept strictly confidential. Your anonymity is important to us, and the data collected will be used for research purposes only.

Please read each question carefully and provide your honest and thoughtful responses. There are no right or wrong answers; we are interested in your personal opinions and experiences.

* Indicates required question

1. Email *

2. I understand the purpose of this research and agree to participate voluntarily. *
(Saya faham tujuan kajian ini dan bersetuju untuk terlibat secara sukarela)

Mark only one oval.

☐ Yes/Ya

PART A

This part contains 3 demographic questions.

3. Current Company *

4. Position *

5. Years of Experience *

Mark only one oval.

- ☐ < 5 Years
☐ 5 to 10 Years
☐ 10 to 20 Years
☐ > 20 Years

PART B

This part contains 6 questions. Answer according to the scale as stated below:

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

6. Do you think the developed framework effectively address the construction site issues in Malaysia? *

Mark only one oval.

- 1 2 3 4 5
Stro ☐ ☐ ☐ ☐ ☐ Strongly Agree

7. Do you think the developed framework is suitable for application in practice? *

Mark only one oval.

1 2 3 4 5

Stro ☐ ☐ ☐ ☐ ☐ Strongly Agree

8. Do you think the developed framework provides a clear and comprehensive guide for the adoption of BIM + VR integration in addressing construction issues on site? *

Mark only one oval.

1 2 3 4 5

Stro ☐ ☐ ☐ ☐ ☐ Strongly Agree

9. Do you think the developed framework can be easily implemented within existing construction companies, especially G7 companies in Klang Valley? *

Mark only one oval.

1 2 3 4 5

Stro ☐ ☐ ☐ ☐ ☐ Strongly Agree

10. Do you think the developed framework has the potential to mitigate construction site issues in Malaysia? *

Mark only one oval.

1 2 3 4 5

Stro ☐ ☐ ☐ ☐ ☐ Strongly Agree

11. In your opinion, describe the overall content of the proposed framework *

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Appendix B

Tables Extracted from SPSS

B1 Non-Parametric Correlations for CM and OE

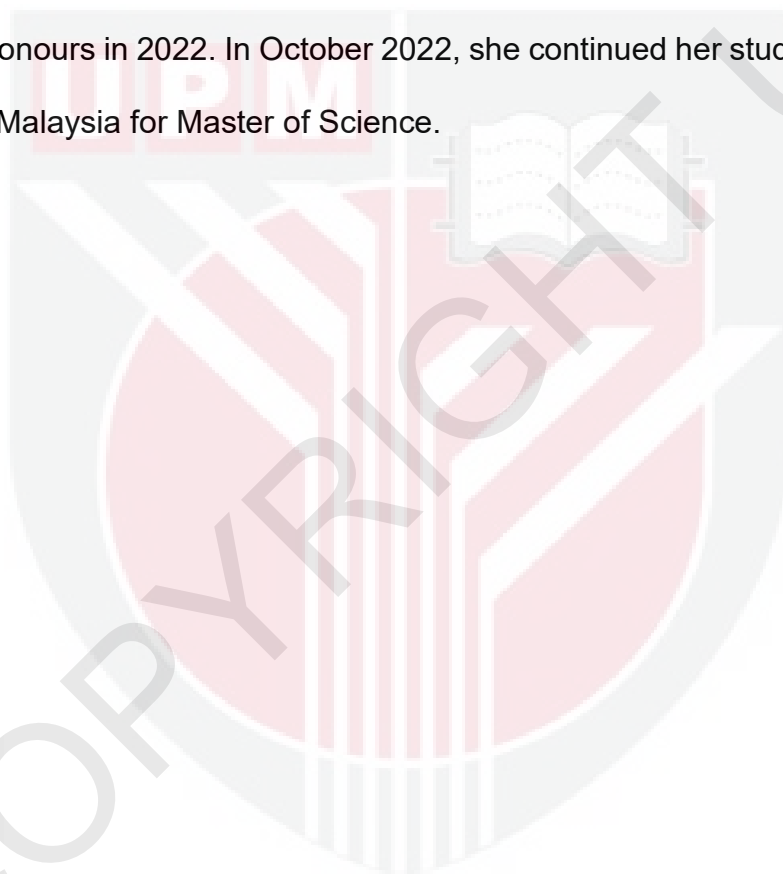
			Correlations							
			Q1	Q4	Q6	Q7	Q9	Q10	Q11	Q14
Kendall's tau_b	Q1	Correlation Coefficient	1.000	.373**	.317**	.197	.264*	.229*	.349**	.185
		Sig. (2-tailed)	.	.001	.003	.080	.017	.044	.003	.100
		N	69	69	69	69	69	69	69	69
	Q4	Correlation Coefficient	.373**	1.000	.357**	.456**	.076	.368**	.537**	.395**
		Sig. (2-tailed)	.001	.	.001	<.001	.496	.001	<.001	<.001
		N	69	69	69	69	69	69	69	69
	Q6	Correlation Coefficient	.317**	.357**	1.000	.506**	.402**	.358**	.331**	.260*
		Sig. (2-tailed)	.003	.001	.	<.001	<.001	.001	.003	.016
		N	69	69	69	69	69	69	69	69
	Q7	Correlation Coefficient	.197	.456**	.506**	1.000	.337**	.474**	.412**	.471**
		Sig. (2-tailed)	.080	<.001	<.001	.	.002	<.001	<.001	<.001
		N	69	69	69	69	69	69	69	69
	Q9	Correlation Coefficient	.264*	.076	.402**	.337**	1.000	.295**	.282*	.361**
		Sig. (2-tailed)	.017	.496	<.001	.002	.	.008	.013	.001
		N	69	69	69	69	69	69	69	69
	Q10	Correlation Coefficient	.229*	.368**	.358**	.474**	.295**	1.000	.594**	.327**
		Sig. (2-tailed)	.044	.001	.001	<.001	.008	.	<.001	.004
		N	69	69	69	69	69	69	69	69
	Q11	Correlation Coefficient	.349**	.537**	.331**	.412**	.282*	.594**	1.000	.434**
		Sig. (2-tailed)	.003	<.001	.003	<.001	.013	<.001	.	<.001
		N	69	69	69	69	69	69	69	69
	Q14	Correlation Coefficient	.185	.395**	.260*	.471**	.361**	.327**	.434**	1.000
		Sig. (2-tailed)	.100	<.001	.016	<.001	.001	.004	<.001	.
		N	69	69	69	69	69	69	69	69
Spearman's rho	Q1	Correlation Coefficient	1.000	.390**	.345**	.209	.285*	.241*	.360**	.196
		Sig. (2-tailed)	.	<.001	.004	.085	.018	.046	.002	.107
		N	69	69	69	69	69	69	69	69
	Q4	Correlation Coefficient	.390**	1.000	.393**	.477**	.083	.380**	.547**	.413**
		Sig. (2-tailed)	<.001	.	<.001	<.001	.497	.001	<.001	<.001
		N	69	69	69	69	69	69	69	69
	Q6	Correlation Coefficient	.345**	.393**	1.000	.546**	.440**	.392**	.354**	.288*
		Sig. (2-tailed)	.004	<.001	.	<.001	<.001	<.001	.003	.016
		N	69	69	69	69	69	69	69	69
	Q7	Correlation Coefficient	.209	.477**	.546**	1.000	.356**	.491**	.423**	.487**
		Sig. (2-tailed)	.085	<.001	<.001	.	.003	<.001	<.001	<.001
		N	69	69	69	69	69	69	69	69
	Q9	Correlation Coefficient	.285*	.083	.440**	.356**	1.000	.311**	.298*	.386**
		Sig. (2-tailed)	.018	.497	<.001	.003	.	.009	.013	.001
		N	69	69	69	69	69	69	69	69
	Q10	Correlation Coefficient	.241*	.380**	.392**	.491**	.311**	1.000	.604**	.338**
		Sig. (2-tailed)	.046	.001	<.001	<.001	.009	.	<.001	.005
		N	69	69	69	69	69	69	69	69
	Q11	Correlation Coefficient	.360**	.547**	.354**	.423**	.298*	.604**	1.000	.447**
		Sig. (2-tailed)	.002	<.001	.003	<.001	.013	<.001	.	<.001
		N	69	69	69	69	69	69	69	69
	Q14	Correlation Coefficient	.196	.413**	.288*	.487**	.386**	.338**	.447**	1.000
		Sig. (2-tailed)	.107	<.001	.016	<.001	.001	.005	<.001	.
		N	69	69	69	69	69	69	69	69

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

BIODATA OF STUDENT

The student, Nasrin Syahirah Binti Zainuddin, was born in Kuala Lumpur, Malaysia, on the 12th of October 1999. She attended her pre-university education at Kolej Matrikulasi Perak under the Science (Module II) programme. She pursued her undergraduate degree at Universiti Putra Malaysia for four years, receiving her Bachelor's Degree in Civil Engineering with Honours in 2022. In October 2022, she continued her studies at Universiti Putra Malaysia for Master of Science.



LIST OF PUBLICATION

Journal

Zainuddin, N. S., Alias, A. H., Abu Bakar, N., Haron, N. A. (2024). Unlocking the Potential of BIM and VR Integration to Address Construction Challenges in Malaysia's Building Industry: A Literature Review. *Journal of Sustainable Civil Engineering and Technology*, 3(1), 10-28. <https://doi.org/10.24191/jscet.v3i1.10-38>

