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Unlocking the Potential of BIM and VR Integration to Address Construction Challenges in Malaysia's Building Industry: A Literature Review

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Abstract

Delays in project completion, cost overruns, safety risks, and poor communication among project stakeholders are just some of the leading causes of the many problems plaguing Malaysian construction projects. The construction sector in this country is suffering from these significant problems, which could be remedied with the help of emerging technologies, including Building Information Modelling (BIM) and Virtual Reality (VR). Integrating Virtual Reality (IVR) and Building Information Modelling (BIM) may help avoid and resolve such problems during construction. The features allow for remote collaboration, enhanced communication and connection, enhanced immersion and interactivity, and reduced costs. This literature review exemplifies the challenge that arose on a construction site, as well as the potential of VR technology in general and its integration in assisting the construction industry in Malaysia with BIM. Based on the comprehensive analysis conducted, it is evident that the integration of BIM and VR presents a vast potential to alleviate and resolve the pressing construction-related challenges afflicting Malaysia's construction industry. The effective integration of these innovative technologies can revolutionise the sector by mitigating cost overruns, reducing project delays, enhancing communication, and improving safety outcomes. Therefore, realising the potential and exploring the possibilities of BIM and VR integration is crucial to overcoming the issues and promoting sustainable growth in Malaysia's construction sector.

Keywords: Construction site; Construction issues; Construction industry; Building Information Modelling; Virtual Reality

1. Introduction

The construction industry holds significant importance for the global economic development of nations. Developing nations, such as Malaysia, are commonly characterised by a growing construction sector. The construction industry plays a crucial role in the national economy due to its dynamic characteristics and close integration with various sectors (Chia et al., 2014; Khan et al., 2014; Berawi et al., 2019). In contrast to other developed countries, the Malaysian construction sector exhibits a relatively diminished impact on the overall growth of its gross domestic product (GDP). Since 2008, Malaysia has experienced a significant and noteworthy development in the proportion of Asia's chosen nations that rely on the construction sector for their gross domestic product (GDP) (Dehdast et al., 2020).

Improved levels of productivity, efficiency, and technological advancement distinguish the modern construction industry in Malaysia. Multiple studies have concluded that several concerns and obstacles negatively impact construction productivity in Malaysia (Olanrewaju & Abdul Aziz, 2015; Khan et al., 2014; Shehu et al., 2014). According to Lachimpadi et al. (2012), the construction industry is challenged to generate significant amounts of waste in terms of time, money, energy, and materials due to the increasing demands for construction developments and large-scale infrastructure projects.

Virtual reality (VR) technology has the potential to significantly transform the construction industry by offering on-site construction workers and professionals real-time, interactive visual information of the site at a 1:1 scale (Zaker & Coloma, 2018). Virtual reality (VR) technology is a crucial component in the design-to-construction process, as it is involved in several stages, such as assessing design alternatives, delivering proposals, identifying and rectifying faults, and addressing construction and serviceability concerns prior to commencing construction (Sampaio, 2018). Moreover, utilising virtual reality (VR) technology enables improved visualisation, hence promoting enhanced communication among many different parties in the construction sector. By utilising VR, it helps to promote a comprehensive understanding of the project as a cohesive entity. Despite the potential advantages of VR integration in construction, the lack of fundamental understanding and expertise among construction employees limits the adoption and deployment of virtual reality (VR) technology in Malaysia.

According to Wang (2021), the utilisation of Building Information Modelling (BIM) and Virtual Reality (VR) technology provides unique benefits in terms of virtual visualisation, information interaction, and management coordination. The capabilities enable the prediction and dynamic control of potential factors in the construction process, thereby introducing an innovative method to the management of construction projects. Facilities management is intricately linked to virtual reality (VR) due to the utilisation of real-time data visualisation from a BIM model facilitated by VR technology. According to a report from Malaysia's Construction Industry Transformation Plan, using tools such as building information modelling (BIM) to enhance sustainability in construction projects is limited among the country's builders (Mamter et al., 2017; Salleh & Phui Fung, 2014).

Integrating virtual reality (VR) into the Building Information Modelling (BIM) solution offers the potential to address challenges related to information retrieval and presentation. Furthermore, it can improve communication effectiveness and problem-solving efficiency within a collaborative and dynamic context. The integration of virtual reality (VR) experiences based on building information modelling (BIM) can yield advantages. However, this endeavour introduces complexities due to the requirement of sophisticated technology and extensive staff training (Wu et al., 2020).

Simultaneously, with the increasing adoption of BIM during this period, a unique virtual reality paradigm emerged inside the architecture, engineering, and construction (AEC) sector (Lyne, 2013). By utilising BIM, the necessary 3D data for visualisation was readily accessible. Additionally, the use of portable and cost-effective head-mounted displays (HMDs) made VR technology more practical and attainable (Johansson et al., 2014). However, more empirical research is needed to investigate the practical applications of immersive virtual reality (VR) in the construction industry. Johansson and Roupe (2024) have identified remaining technical hurdles and barriers that hinder effective integration, which include rendering performance and interoperability issues. Currently, most of the ongoing research in the AEC sector focuses on the development of prototypes for both single- and multi-user VR. However, these prototypes have yet to be tested or evaluated in construction projects (Du et al., 2018).

According to a survey published by McGraw Hill in 2014, over 30% of all projects worldwide utilise BIM; however, the percentage differs across different regions. The BIM adoption rate in various countries as of 2021 is presented in Table 1.

Table 1. BIM adoption rate in different countries (Malaysia Building Information Modelling Report, 2021)

Country	Adoption rate (%)
Malaysia	55
United States	80
United Kingdom	73
Germany	70
Poland	43
Russia	12
Japan	46

Table 1 above shows that the adoption of BIM in Malaysia is higher than in Poland, Russia, and Japan as of 2021. With an acceptance rate of 80% and architectural firms leading the way with a 98% adoption rate, the United States has been at the forefront of BIM development and implementation in the construction sector (Wong et al., 2010). In Malaysia, the implementation of BIM began in 2007 and has yet to experience considerable advancement. Nevertheless, the government has implemented several measures to facilitate the spread of BIM knowledge and enhance the necessary technical proficiency for its adoption. Tahir et al. (2017) found that the adoption rate of BIM in Malaysia has significantly declined since its debut in 2009. This decline can be attributed to insufficient research and limited involvement from the government and clients in the adoption process.

With the increasing usage of BIM in Malaysia, it implies that a significant number of industry players are aware of BIM. However, the majority of individuals in the industry possess only a superficial understanding of BIM and lack the necessary expertise to effectively apply and adapt it, particularly within the private sector. Lee et al. (2022) conducted a study that found a positive association between the perceived utility and ease of use of BIM-VR technology and its benefits. The study suggests that users will likely embrace the new developments brought about by this technology. With the increasing spread of BIM expertise, the general adoption of BIM-VR technology will also require significant time. Nevertheless, it is reasonable to assert that the current generation of industry players is at ease with the modifications and would readily embrace such technology, notwithstanding the accompanying difficulties.

2. Research Method

Since this study is a literature review, a thorough literature search was done to identify all relevant sources, including journal articles, conference papers, websites, blogs, books, and electronic media that are relevant to the construction industry and the adoption Virtual Reality (VR) and Building Information Modelling (BIM) integration in the construction industry. Nowadays, most literature searches are conducted using computers and electronic databases because computers and electronic databases provide access to large amounts of material that can be obtained more readily and rapidly than through a manual search (Younger, 2004). There are numerous electronic databases, and the search database used for this study was SCOPUS to find relevant publications. SCOPUS was chosen since it is the largest citation database of research literature and quality web sources, and other databases were also used for full article download and data validation. Additionally, other papers published that are very closely related to performance research were also considered to supplement the literature.

The keywords used in the process of article retrieval are “construction industry”, “construction site problems”, “construction issues”, “virtual reality”, “building information modelling”, and “Malaysia”, as shown in Table 2. 1,847 papers were retrieved from the SCOPUS database using the Preferred Reporting System for Systematic Review and Meta-Analyses (PRISMA) method. Exclusion and inclusion criteria are applied to shortlist the articles retrieved from the search.

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First, duplicated articles were removed, and since there was no duplicate, no article was removed. The articles' publication year was taken into consideration, and it was set between 2010 and 2024. In addition, the article types were also filtered, and the articles included are only from articles, conference papers and reviews, and book chapters. After the initial screening, 379 papers were retrieved, and only Open-Access publications were included in this review study. Non-English articles were also excluded from the articles.

Table 2. Summary of the search string

Search Engine	Search String	Results
Scopus	(TTLE-ABS-KEY("construction industry" OR "construction issues" OR "construction site problems" OR "virtual reality" OR "building information modelling") AND TITLE-ABS-KEY (Malaysia))	1,847
	AND PUBYEAR > 2010 AND PUBYEAR <2023	1,724
	AND (EXCLUDE (DOCTYPE,"dp") OR EXCLUDE (DOCTYPE,"no") OR EXCLUDE (DOCTYPE,"bk") OR EXCLUDE (DOCTYPE,"ed"))	1,711
	AND (LIMIT-TO (LANGUAGE, "English")	1,709
	AND (LIMIT-TO (SUBJAREA, "Engi")	988
	AND (LIMIT-TO (OA, "all")	379
Total published articles from Scopus: 1,847 After removing duplicated articles: 1,847 After first screening: 379 After title and keyword screening: 291 After abstract screening: 107 After full-text screening: 67 Total articles used in the study: 67		

The articles were sorted based on the title, keywords, and abstract to determine their suitability for this literature review. Since 40 articles did not fit the review objectives, they were excluded. Following an abstract-based filtering and review process, 88 papers were not included in the final evaluation. Following that, a full-text screening was done to determine whether the articles' content was appropriate for inclusion in this review, and 31 were excluded. Thus, only 67 papers were included in this review. The remaining articles after screening are categorised into several sections based on the contents that will be discussed further in this review, which are:

1. The prevalent construction issues and site problems that occur in Malaysia.
2. The pattern of the construction industry in Malaysia.
3. The adoption of Building Information modelling in the Malaysian construction industry.
4. The adoption of virtual reality in the construction industry.
5. The integration of virtual reality and building information modelling in the construction industry.

Figure 1 below shows the flowchart of the article screening procedure for SCOPUS in accordance with PRISMA 2020.

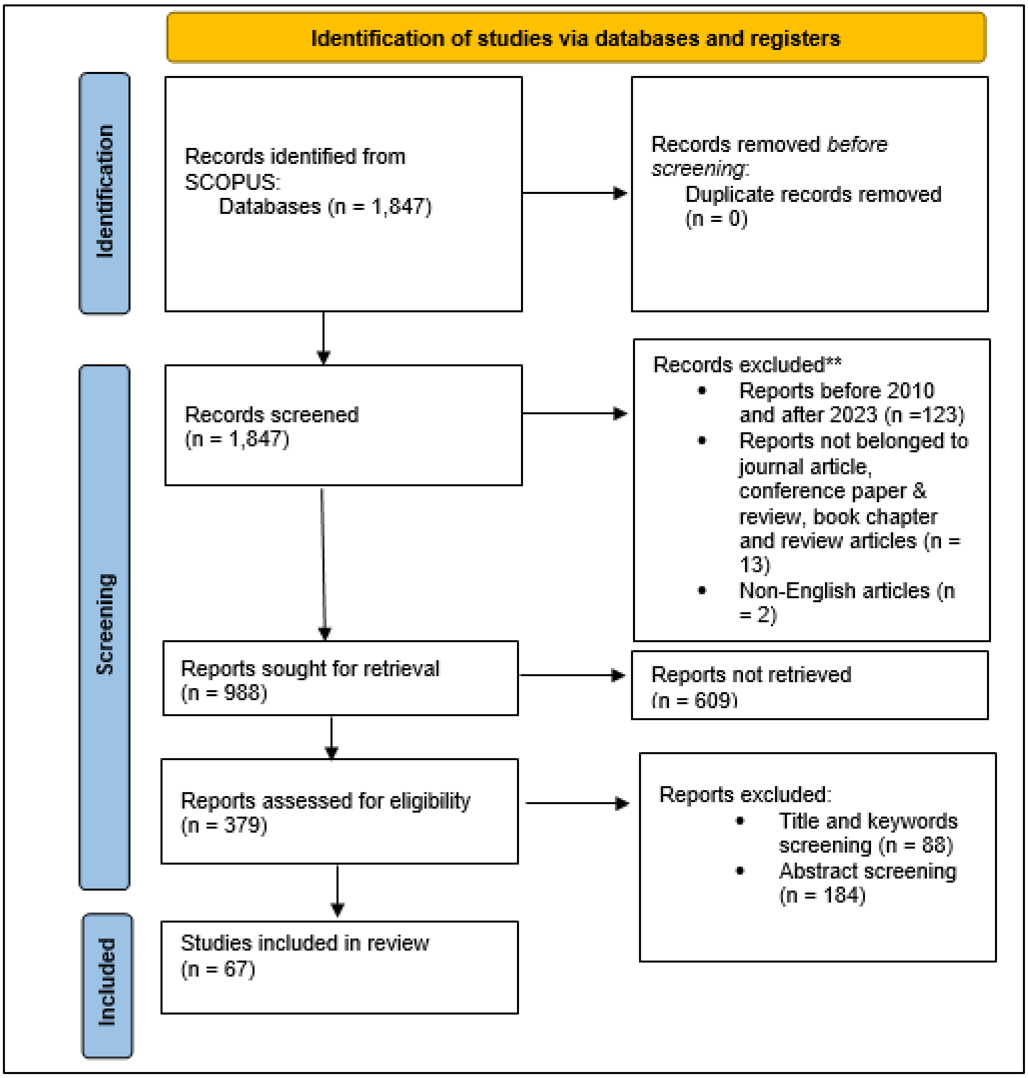

Figure 1. Flowchart of articles screening procedure for SCOPUS according to PRISMA 2020.

3. Construction Industry in Malaysia

The construction industry encompasses a range of activities, such as the planning, physical construction, modification, maintenance, and demotion of buildings, alongside the implementation of engineering projects and other architectural structures (Olanrewaju et al., 2017). The management of infrastructure development plays a pivotal role in shaping the trajectory of a nation's technological and technical advancements, ultimately leading to enhanced sustainability. When evaluating the significance of the construction sector in terms of its contribution to global GDP and employment generation, it is justifiable to characterise this industry as the "foundation" of the global economy. The significant importance of the gross domestic product (GDP) in economic stabilisation is widely recognised. With a global value of USD 1.7 trillion, the construction industry contributes around 5 to 7 percent of the GDP (Kenny, 2007).

In recent years, the construction industry in Malaysia has emerged as a crucial sector within the country, primarily due to its inherent adaptability and its ability to establish both forward and backward ties with other sectors (Chia et al., 2014; Khan et al., 2014; Berawi et al., 2019). According to Khan et al. (2014), the Malaysian construction sector has experienced significant modernisation, efficiency, and technological capabilities. This progress has enabled local companies to expand their operations by undertaking more complex and sizable infrastructure projects that necessitate cutting-edge technology. The industry involves numerous elements, encompassing many contractors, workers, developers, client organisations (governmental and private), management personnel, engineering consultants, architectural consultants, surveying consultants, manufacturers, material suppliers, and plant hirers. The construction industry in Malaysia has experienced notable changes since the independence of Malaysia in 1957, evolving from a low-tech sector with heavy reliance on manual work and craftsmanship to one that possesses the capacity to create modern structures and infrastructure. The evolution process is distinguished by the extensive use of mechanised manufacturing methods and the incorporation of advanced technologies (Kamal & Flanagan, 2012).

Malaysia's construction industry has expanded quickly in recent years, but there have been a number of challenges along the way. Numerous researchers assert that the construction sector in Malaysia is encountering challenges that hinder its optimal operational performance. Time delays and cost overruns are prevalent issues in the construction sector, necessitating their identification and resolution (Aziz & Hafez, 2013; Koushiki et al., 2005). The Malaysian construction sector needs help in successfully implementing government policies and significant challenges are encountered in implementing government policies, specifically regarding incorporating and utilising emerging technology to improve industry performance and productivity. The study conducted by Ibrahim et al. (2010) indicated that the poor use of technology has been identified as a potential factor contributing to the low productivity within the industry. The current practices and procedures implemented by the government, mainly through the Construction Industry Development Board (CIDB), need to be revised to address and acknowledge the significant challenges contractors encounter effectively. These challenges apply to the contractors' ability to adopt and utilise technology and their potential to derive advantages from the latest technological advancement. The guidelines and recommendations proposed exhibit limited influence during the development phase and frequently encounter challenges during the implementation stage.

3.1. Construction Delays

Construction delays, as defined by Assaf and Al-Hejji (2006), refer to instances where the completion date of a project exceeds the initially scheduled timeframe. The present circumstances have a detrimental influence on all parties involved, with the financial consequences particularly evident. Delays are commonly acknowledged as a substantial obstacle that presents a possible hazard to the punctual completion, financial expenses, and general quality of construction projects. However, it should be noted that the problem of construction delays is not limited to Malaysia alone, as it is a widespread occurrence globally. According to Sambasivan and Soon (2007), the comprehensive and frequently adverse outcomes linked to construction delays provide more evidence for the widespread nature of this issue. Despite the numerous hurdles and issues encountered in the construction industry, construction project delays are considered a crucial aspect of the construction management process. It is the determining factor for the overall success of projects within Malaysia.

Delays within the construction sector are commonly identified as reduced operational efficiency and production (Sanni-Anibire et al., 2020). Furthermore, it has been found that surpassing the designated time limit leads to supplementary costs (Memon et al., 2011), thus establishing delays as a crucial metric for assessing performance. Delays are commonly acknowledged as a significant obstacle to the effective implementation of a project (Trauner, 2009). The delays mentioned above significantly and negatively impact the stakeholders' interests since they consistently result in increased costs (AlSeaimi et al., 2013; Azhar & Choudhry, 2016). In cases where projects have delays, it is customary for them to be either extended or expedited, accumulating supplementary expenses. The impact of an efficient and timely management strategy on project success parameters is significant, as it can effectively prevent difficulties from increasing and consequently lead to delays in their resolution (Shrivas & Singla, 2020).

The causes of time delays in construction projects are subject to diverse perspectives, as delays are a prevalent occurrence in nearly all construction activities. Furthermore, the extent of these delays exhibits significant variation among different projects. According to the research conducted by Yap et al. (2019), the five most significant causes contributing to project delays and inefficiencies were identified as “insufficient planning and scheduling”, “excessive change of orders initiated by customers or clients”, “inadequate site management and supervision”, “incompetent sub-contractors”, and “financial difficulties faced by contractors”. Most of the causes and factors are related to management issues, as effective planning and management are crucial in expediting project timelines and compensating for time lost during delays at various project stages (Sambasivan & Soon, 2007). Many academic studies have found that the problem is persistent and hard to solve because there is not enough knowledge being accumulated, especially because mistakes keep happening in different projects (Love et al., 2018). However, it is essential to note that delays and additional costs in construction projects are highly likely to occur if the root causes are not identified and addressed (Ahmad et al., 2014).

Garemo et al. (2015) stated that nearly all construction projects cost more than expected and take longer than expected. Delays in the construction project could hurt the project’s performance for a variety of reasons. Reduced efficiency and productivity among the workers involved in a construction project is a hallmark of delays. Delays in this field can lead to several problems, such as disputes in court, an increase in costs, a halt in progress, a decrease in output, a loss of profits, and even the termination of contracts. Delays will hurt the project's stakeholders regarding work progress, mutual relationships and communication, monetary matters, and the potential for conflicts, disputes, and other legalities among the project's parties (Semple et al., 1994; Yates & Epstein, 2006).

According to Alkass et al. (1996), while certain contract parties acknowledged the extra period and expenses incurred due to delays, conflict often arose between the owner and contractor regarding the contractor’s eligibility to seek reimbursement for the additional costs. These situations typically involve questions about the legitimacy of the facts, casual factors, and contract interpretation. Delays encountered throughout a building project can have significant adverse consequences, including losing the project’s prospective financial advantages. Delays are widely acknowledged as significant factors damaging the success profile of most projects, negatively impacting the interests of project stakeholders by escalating project costs (AlSeaimi et al., 2013; Azhar & Choudhry, 2016).

A survey was undertaken by Kumaraswamy and Chan (1998) to assess the relative relevance of factors contributing to delays in construction projects in Hong Kong. The findings of the study revealed that there were five primary factors contributing to project delays. These factors included inadequate site management and supervision, unanticipated ground conditions, sluggish decision-making processes involving all project teams, modifications initiated by the client, and essential alterations to the scope of work. This finding suggests that a significant portion of construction delays on site can be attributed to communication challenges among the various parties involved, including stakeholders, in effectively addressing and resolving issues encountered during construction activities.

3.2. Cost Overrun

Himansu (2011) stated that the term "cost overrun" refers to the discrepancy between the actual expenses incurred during a project and the initial budget allocated for it. Recent research has indicated that there is a rising concern regarding cost overruns within the construction industry (Cindrela Devi & Ananthanarayanan, 2017). Despite the increasingly significant implications involved, construction projects have exhibited a recurrent tendency to exceed their designated budgetary allocations. The occurrence of cost overruns in construction projects carries the inherent risk of transforming them into defaulted projects, hence leading to significant repercussions for all parties involved in the project's execution (Cantarelli, 2009; Olawale & Sun, 2010). Angelo and Reina (2002) assert that cost overruns pose a significant concern in both developed and developing nations.

According to Vaardini et al. (2016), cost overruns in developing nations are particularly pronounced, often surpassing 100% of the initial project cost, primarily as a result of inadequate resource management. Maintaining control over cost performance is crucial in order to ensure that construction projects remain within the projected budget. Hence, the implementation of project cost management, encompassing project resource allocation, cost estimation, cost monitoring, and cost allocation, is vital to ensuring adherence to the predetermined project budget.

Chitkara (2011) identifies many primary controllable factors that contribute to cost overruns in projects, which encompass, but are not restricted to, the subsequent: [1] insufficient project formulation, characterised by inadequate field inquiry, insufficient project information, inaccurate cost estimates, lack of experience in project formulation and feasibility analysis, deficient project assessment resulting in inaccurate investment decisions, and [2] insufficient planning for implementation, including inadequate allocation of time, resources, and equipment, failure to predict inter-linkages, inadequate organisational structure, and inadequate cost planning. Two key factors contributing to the challenges in contract execution are inadequate contract planning and management, namely in the areas of pre-contract actions and post-award contract management. Additionally, the absence of appropriate project management during execution can lead to issues such as inadequate job performance, delays, changes in scope of work and location, as well as concerns related to law and order.

Every construction project experiences some degree of cost overruns, defined as expenses incurred beyond the original budget (Azis et al., 2013), though the extent to which this occurs varies from job to job. The most common causes of budget overruns on construction projects are payment delays, difficulties securing necessary funds, and increases in the project's scope. Flyvbjerg et al. (2002) found that ineffective management was the primary cause of cost overruns in 90% of projects. In addition, time overruns can be the root cause of cost overruns, two of the most important metrics of a project's success or failure.

In Malaysia, only 46.8% of government-funded projects and 37.2% of privately-funded projects were completed without going over their original budgets in 2016. (Abdullah et al., 2009; Ibrahim et al., 2010; Sambasivan & Soon, 2007). Material price fluctuations, cash flow and financial difficulties, and ineffective site management and supervision were identified as the top three causes of construction cost overruns in Malaysia (Abdul Rahman et al., 2013). According to Sambasivan and Soon (2007), poor construction management is the most common cause of construction delays worldwide. This is due to the fact that ineffective management and a lack of a formalised cost control system are at the root of these issues (Sriprasert, 2000). Cost overruns, especially during the design phase, were found to be directly proportional to the degree to which communication and coordination issues were present (Sambasivan & Soon, 2007).

Patil (2017) claims that many contractors are unable to effectively plan on-site, organise labour, and monitor and control the work in progress. As a result, managing construction projects in Malaysia and elsewhere should give serious consideration to the problem of cost overruns. The solution relies on cost control measures like cash flow management and project accounting, which are implemented as part of project cost management to ensure that the project stays within its allotted budget (Vaardini et al., 2016). Given that most of the causes of cost overruns are related to poor resource management, incorporating an effective resource management system within construction projects is one possible solution to lessen the impact of cost overruns. Moreover, a crucial activity for delivering projects successfully and minimising cost overruns is effective communication between stakeholders (Yong & Mustaffa, 2012).

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3.3. Safety Hazards

Construction site safety is of utmost significance due to its widely recognised status as one of the most hazardous sectors globally. In contrast, a safety hazard refers to a tangible threat that jeopardises individuals' well-being, physical integrity, personal belongings, and privacy. Construction accidents correlate with many project parameters, including site layout, materials, tools and equipment, and trade workforces, which collectively contribute to a precarious site environment. According to previous studies constructed by Waehrer et al. (2007) and Yim et al. (2006), it has been observed that the fatality rate within this particular industry surpasses that of other industries. In the study conducted by Sousa and Teixeira (2004), it was observed that construction workers exhibited a fatality rate that was three times higher and an injury rate that was two times higher in comparison to workers in alternative industries.

Numerous scholarly research studies related to construction safety have posited that a significant proportion of incidents occurring on construction sites may have been mitigated and averted by implementing a comprehensive and consistent safety management framework encompassing planning, education and training, and inspection. The inclusion of construction safety management within the framework of construction project management is necessary due to its comprehensive consideration of the various factors influencing construction safety and the methodologies employed for evaluating construction safety risks. The safety management process should be carefully designed to facilitate identifying and acknowledging safety concerns by site managers and trade workforces and promote effective communication among them throughout the construction process (Sawacha et al., 1999).

Despite its significance, the construction industry is known for its inherent dangers due to the high number of accidents on construction sites and the less-than-satisfactory record it has regarding occupational health and safety (Jannadi & Bu-Khamsin, 2002). Since most workers in developing nations are employed by small and medium-scale industries that do not adhere to the minimal requirements and guidelines set forth by the authorities, the risk of suffering a work-related injury is 10 to 20 times higher than in developed countries. Although modern technology has boosted industrial output, it has also made workers' lives more difficult by increasing the incidence of injuries and illnesses that lead to disability, as Farooqui et al. (2008) pointed out. A risk-free workplace is essential for increasing manufacturing output, efficiency, and quality. Due to the construction industry's higher-than-average accident fatality rate, it is imperative that proper safety measures, such as routine safety inspections, be implemented.

According to official statistics published by the Malaysian Ministry of Human Resources, construction workers are more likely to become disabled or die on the job than employees of any other industry. As stated by the Social Security Organisation (SOCSO), there were 656,555 workplace accidents in Malaysia in 2016. Of these, it is estimated that 42,775 were construction-related, or 6.5%. The lack of use of Personal Protective Equipment (PPE) and a failure to follow safe work procedures result in the majority of construction accidents in Malaysia, the majority of which involve falls, especially from tall heights (Williams et al., 2017). Human error, insufficient protective gear, sloppy project management, and faulty machinery are significant contributors to construction accidents in Malaysia (Ali et al., 2010).

The layout of construction plays a pivotal role in determining the project's overall success. It has a direct impact on the progression of subsequent construction activities, the level of efficiency achieved in their execution, the overall cost implications, the transportation distance of building materials, and the security measures implemented at the site (Ning et al., 2018; Sanad et al., 2008). Based on the research conducted by Malekitabar et al. (2016) and Ning et al. (2018), it has been found that a significant proportion of incidents can be effectively addressed through the implementation of straightforward design modifications, resulting in the elimination of the underlying hazards responsible for 46.8% of these accidents. Consequently, enhancing safety management

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requires an increased emphasis on proactive measures. The safety manager needs to conduct routine inspections daily, weekly, and monthly to assess the effectiveness of planned preventive measures and identify any potentially unsafe behaviours exhibited by the workforce. During these safety inspections, the safety manager should document and record any unsafe conditions or inadequate utilisation of preventive measures. Subsequently, this information should be communicated to relevant trades to mitigate the risk of accidents and fatalities (Choudhry et al., 2008).

Several prominent visualisation techniques, including building information modelling (BIM) (Kiviniemi et al., 2011), game technologies (Guo et al., 2011; Li et al., 2011), virtual reality (Hadikusumo & Rowlinson, 2002), and augmented reality (Mizuno et al., 2004), have been employed to enhance existing safety management practices. The documented advantages of these strategies are enhanced working memory capacity, more excellent cognitive processing of spatial information, and higher reliance on past experience and memory (Bowman et al., 2006; Han et al., 2009; Keller & Tergan, 2005).

3.4. Poor Communication

According to the Project Management Body of Knowledge Guide, communication in the construction industry can be described as the reciprocal transmission of project information and procedures to establish a comprehensible platform between the sender and the recipient. Effective communication influences a project's success (Fichet & Giraud, 2007). Project management is identified as a prominent knowledge area within the field of project management, as stated in the Project Management Body of Knowledge Guide. This knowledge area encompasses the necessary processes to guarantee the timely and suitable generation, collection, distribution, storage, retrieval, and ultimate disposition of project information. Moreover, communication is a critical element in project management that permeates all other facets (Olaniran, 2015). Emmit and Gorse (2006) assert that effective communication serves as a crucial managerial competency, with leadership and decision-making processes being projected by proficient communication abilities.

Effective communication is crucial in the construction industry as it enhances collaboration and cooperation among many stakeholders involved in construction projects (Gamil & Abdul Rahman, 2018). However, it is essential to note that communication between parties is only sometimes clearly stated and effective. In numerous instances, it proves ineffective, leading to lousy communication (Wikforss & Lofgrenn, 2007). Research has highlighted poor communication as a significant factor in construction delays (Abdul Rahman et al., 2013). The primary objective is to ensure efficient, productive, and adequate communication procedures within the construction sector and address sufficient communication about projects (Berntzen, 1988). Multiple studies have discovered that the industry has substantial challenges in achieving efficient and prosperous communication throughout the project lifecycle. Effective communication is crucial throughout all construction phases, which are design, production, organisation, and management (Mohammed et al., 2016). According to Azis et al. (2013), facilitating efficient communication is crucial in enabling timely information exchange and accurate decision-making when confronted with development issues. The recognition and cultivation of open channels of communication are acknowledged as crucial factors for the overall success of a project, beginning in its early stages and continuing throughout its development.

According to Kazi (2005), many issues within the construction industry can be attributed to inadequate or absent communication channels. Insufficient communication within the corporate world can result in several ramifications, including but not limited to cost and time overruns, disputes, and ultimately, project failure. Insufficient communication can be identified as a contributing factor to many delays, such as slow information flow, flawed communication channels, inaccurate design and interpretation, the need for reworks, and other related issues (Dainty et al., 2006; Tipili et al., 2014; Love & Li, 2000; Sambasivan & Soon, 2007). On the other hand, a lack of communication impedes the essential coordination among the stakeholders, leading to errors, exclusions, disputes, and challenges related to feasibility that necessitate additional modifications in the form of reworks (Yap & Tan, 2021). Miscommunication frequently leads to the need for reworks at different phases of a project's lifespan, resulting in additional labour and expenses. The successful and comprehensive completion of the construction necessitates a mutual understanding of the information provided by both sides. Disputes are common in the construction industry, and numerous studies have found that poor communication between parties is a significant cause. Poor communication can affect the project's time, money, and quality (Gebken & Gibson, 2006) and disparities in the educational and cultural backgrounds of the parties involved in a construction project and their individual communication skills can lead to misunderstandings during the project's delivery phase (Cheng et al., 2001). However, the construction industry is notoriously complex, leading to many simultaneous communication problems that can only be solved by adopting proper channelling to manage and control the communication process (Fichet & Giraud, 2007). A lack of proper data channels and accurate data transfer significantly hinders effective communication in the construction industry (Lee & Bernold, 2008). All parties involved can benefit from being informed of the situation at all times and working together to find solutions if regular meetings and clear lines of communication are in place.

In addition, improving communication fosters collaboration, which is essential for cultivating trust, facilitating collective decision-making, and promoting effective participation. This, in turn, reduces the number of modifications and reworks required during the construction process, ensures adherence to regulations and standards, enhances the quality of deliverables and strengthens project control (Yap et al., 2019). Notably, the interconnectedness of communication, trust, and information sharing significantly impacts the collective learning process among team members, both inside individual projects and across several projects. In regards to this matter, the key elements crucial for a project's success encompass proficiency, unwavering dedication, and efficient communication (Yong & Mustafa, 2013).

4. Virtual Reality

Since the early 21st century, many technological devices, such as mobile phones, personal computers, all-in-one models, and standalone gadgets, have been equipped with wireless communication capabilities and integrated virtual reality features. Virtual reality enables individuals to engage in the exploration, first hand experience, and critical assessment of a comprehensive virtual model, fostering a sense of immersion (Bordegoni & Rizzi, 2011; Paes et al., 2017). Milgram and Colquhoun (1999) initially developed a comprehensive taxonomy of the visualisation system utilised in positioning virtual reality (VR). This taxonomy outlines the varying degree to which the concepts of "virtual" and "real" are integrated to construct a visualisation environment. Virtual reality (VR) technologies encompass visualisation techniques that aim to provide a sense of complete immersion in a virtual environment. These technologies have garnered significant interest in recent times due to their potential to enhance communication in professional settings and shared areas (Wang et al., 2018). The following diagram illustrates the global count of virtual reality users actively engaged with the technology between 2014 and 2018.

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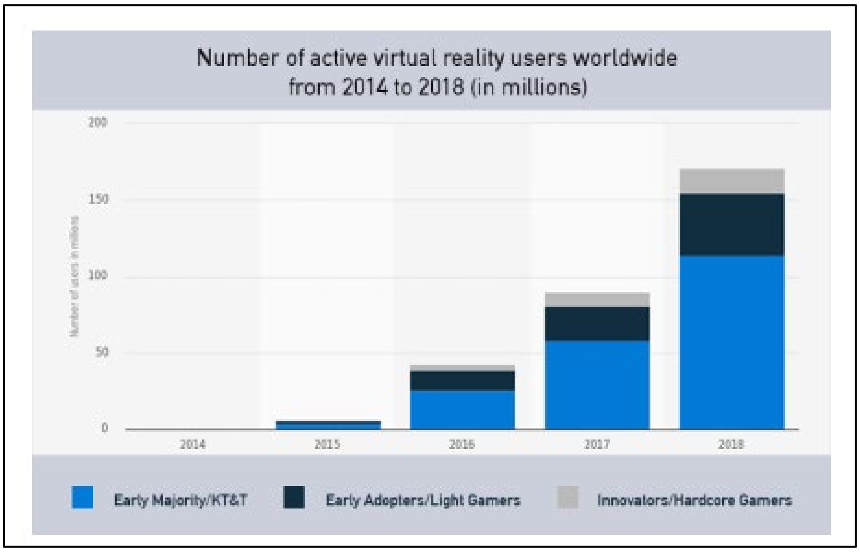

Figure 2. Number of active virtual reality users worldwide from 2014 to 2018 (in millions) (Cleveroad, 2016)

Sampaio (2018) claims that virtual reality technology is an effective tool for tracking the progress of building projects because it enables participation in the building process and the visualisation of different stages of the building. Users can experience a real sense of presence in a potentially dangerous situation by manipulating a 3D/BIM model in virtual reality (VR) (Poussard et al., 2014). Before starting construction, architects, engineers, and contractors may use virtual reality (VR) to visualise project designs as digital representations of the finished result. By providing a spatially accurate visual representation of the design object, virtual reality (VR) can be a useful tool for comprehending digitally planned architecture (Zaker & Coloma, 2018).

Virtual reality (VR) has many potential applications in the architecture, engineering, and construction (AEC) industry, including in the areas of collaboration, project management, and education (Pratama & Dossick, 2019; Delgado et al., 2020). Virtual reality technology is an invaluable tool for monitoring the growth of the construction industry because it enables participation in and observation of different stages of development. This is because virtual reality can be used before construction begins, from evaluating design options and displaying bids to fixing design flaws and resolving construction and usability issues. With virtual reality (VR), key players in the construction industry can better understand the project and improve their ability to interact with one another.

The practical application of virtual reality technology has undergone significant advancements and has been successfully implemented in various industries. This new technology has demonstrated its value within the construction industry by effectively reducing rework time, enhancing monetary savings, and uncovering design errors. According to Whyte (2017), virtual reality has various applications in the construction industry, including design, collaborative visualisation, and improving the construction process. It serves as an effective medium for building design, offering real-time manipulation of 3D visualisations that can be explored collaboratively to examine different stages of construction.

Incorporating virtual reality (VR) technologies within the construction sector holds the potential for widespread utilisation over a project's life cycle, encompassing design, construction, and post-construction stages. Numerous areas of application for virtual reality (VR) have been explored within the construction industry, including visualisation and collaboration, safety management, and construction engineering education and training, as these areas have been extensively studied by various researchers (Bouchlaghem et al., 2005; Boton, 2018; Wolfartsberger, 2019; Du et al., 2018; Li et al., 2012).

The AEC industry is strongly dependent on visual communication, and it is widely acknowledged that the advancements in virtual reality (VR) technology have benefited this industry (Kim et al., 2013). According to Delgado et al. (2020), a significant determinant for the adoption of virtual reality (VR), as well as augmented reality (AR), in the construction sector is their potential to enhance the execution of construction projects. Additionally, these technologies can enhance project comprehension, productivity, communication, and collaboration.

In a study conducted by Behzadi (2016), it was discovered that virtual reality (VR) offers advantages in project scheduling, communication and information retrieval, safety management practices, and man labour hours. Although there is a body of research investigating the utilisation of virtual reality (VR) in different nations, there needs to be more studies concerning its deployment within the construction industry of developing countries. More attention should be given to exploring techniques for integrating VR technology in this context. One significant constraint in integrating virtual reality technology within the construction sector pertains to the prevailing assumption that this technology remains in a developing stage and still needs to be capable of being effectively employed in practical applications.

4.1 Immersion and Interactivity

Interactivity relates to the degree of flexibility and control the user has over the experience (Makransky & Peterson, 2021), while immersion can be interpreted as the object level of sensory realism provided by VR systems (Bowman & McMahan, 2007). By simulating real-world environments and enabling users to interact with them, virtual reality (VR) can deliver highly immersive experiences. Recent research suggests that extreme immersion and interactivity set virtual reality apart (Johnson-Glenberg, 2018; Makransky & Peterson, 2021).

Furthermore, VR allows users to interact naturally and intuitively with the virtual environment by moving their bodies, hands, and heads to navigate the virtual space and interact with its contents. The 360-degree environment creation features of the virtual reality markup tools and the immersive nature of the VR experience were more conducive to teamwork than the features of the building information modelling (BIM) markup tools (Asl & Dossick, 2022). Furthermore, it is argued that the egocentric experience of the spaces and users' ability to better understand the relative sizing of those spaces to their scale will be supported by being able to see the model in its entirety, as in a fully immersive system such as head-mounted displays or room-scale virtual reality (Kalisperis et al., 2002).

Recent research suggests that virtual reality's ability to provide a truly immersive and interactive experience sets it apart from more conventional forms of education (Makransky & Peterson, 2021). While both immersion and interaction improved the sense of physical presence, it was clear from the latter’s effect that it was more crucial to the experience and embodied learning in low-immersion environments. With the advancement of virtual reality technology, designers can now examine and interact with equipment models and prototypes in a more realistic setting.

4.2 Simulation

Simulation is defined as modelling the behaviour of a system through the use of the software (Mourtzis et al., 2014). Virtual reality (VR) simulation entails recreating actual environments, activities, and events within a computer program. The point of a virtual reality (VR) simulation is to provide a realistic environment in which users can train and perfect their abilities without risk. Virtual reality (VR) is one of the cutting-edge computer technologies for creating engaging simulated settings. Simulating the real world allows users to interact with virtual surroundings using sensors.

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Virtual reality (VR) is a technology that immerses the user in a computer-generated environment and allows for natural interaction between the user and the environment through the use of their senses of sight, sound, and touch (Quint et al., 2015; Jensen & Konradsen, 2018). Sampaio (2018) claims that virtual reality (VR) technology enables users to fully immerse themselves in a 1:1 scale, providing an accurate sense of presence in space that has yet to be built, allowing them to observe the artificial world by walking through the model and also reach out to objects in real-time. Virtual reality (VR) simulations have the potential to be extraordinarily lifelike and immersive, giving users the feeling that they are actually inside the simulated environment, and by providing a safe and realistic setting, they can aid in improving learning and skill development.

A virtual reality (VR) framework is presented for modelling and simulating work processes and viewing multisource analytical data from different computer-aided engineering (CAE) programs (Hu et al., 2018). With the help of simulation, a virtual reality (VR) application can check logic, eliminate disagreement, and reduce expenses, particularly in the planning and design phases of a building project (Karagiannis et al., 2020). The combination of the most immersive and intuitive technology, virtual reality (VR), and the safety of a simulated world makes for a powerful tool (Karagiannis et al., 2020). The concept behind this strategy is depicted in the following figure.

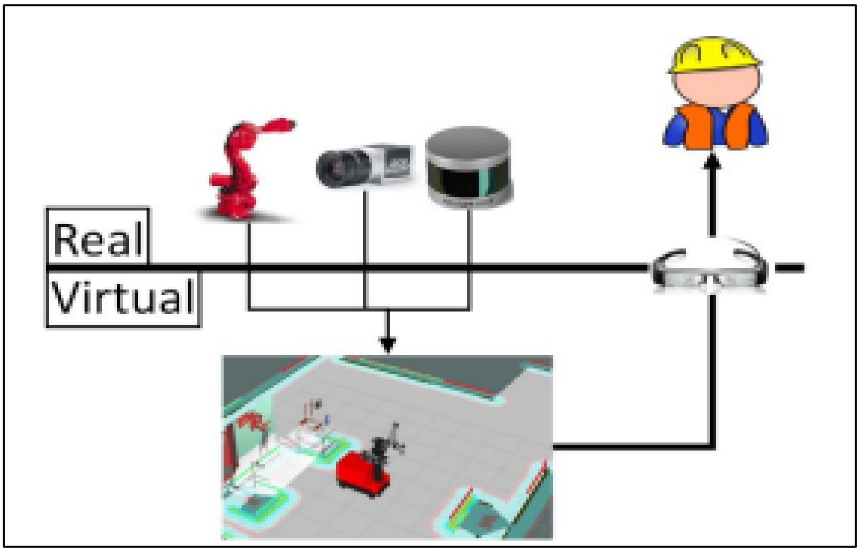

Figure 3. Simulation and VR applications approach (Karagiannis et al., 2020)

Based on the figure by Karagiannis et al. (2020), as shown in Figure 3 above, the simulation aims to replicate the actual environment, incorporating the resources intended for the operator's use. Meanwhile, the VR application allows users to observe the environment via simulated sensors and respond to it through VR interfaces.

4.3 Education and Communication

Most virtual reality (VR) simulations in education are used for design visualisation (Castronovo et al., 2020; Nikolic & Windess, 2019), construction safety education (Le et al., 2015; Sacks et al., 2013), equipment operation, and structural analysis (Abdelhameed, 2013). Therefore, due to contextual variations and their unique features, educational VR applications still fall short of offering straightforward VR solutions to consistently realise the benefits mentioned above, revealing a plethora of conceptual and empirical challenges in how VR is conceptualised and justified in construction education from the pedagogical, methodological, and theoretical

perspectives (Ventura et al., 2022).
Virtual reality serves not only as an entertainment tool but also as a potent means for studying and enhancing communication, offering capabilities for remote communication, collaboration, and interactive experiences. The utilisation of virtual reality in remote communication applications has been demonstrated to achieve better co-presence and shared emotional understanding compared to artificial user avatars (Li et al., 2019; Smith & Neff, 2018). Previous research indicates that immersive and communicative point cloud reconstructions are more effective for this purpose. Fully immersive virtual reality applications enhance the sense of presence and immersion, showcasing potential as a substitute for traditional teleconferencing and telepresence methods. This technology enables the exploration of different realities and alternative experiences. In the realm of education, virtual reality presents a more effective way of emphasising concepts through visualisations, creating interest among learners and surpassing traditional methods of learning.

Recently developed multi-user sessions in immersive virtual reality have demonstrated their ability to enhance productivity, particularly in design review meetings and model inspections (Heinonen et al., 2022). Incorporating multi-user co-presence in a virtual reality model has added value by facilitating improved information sharing and collaboration among participants. Enhancements such as scaling 1:1, stereo vision, and the ability to observe and point at what others are seeing contribute to enhanced communication and understanding, as highlighted by Johansson and Roupe (2022). Virtual reality's capacity to incorporate various languages within the software addresses language barriers, eliminating a significant obstacle to effective communication.

4.4 Design and Visualisation

Virtual reality technology can be used to develop interactive 3D models and simulations in architecture, industry, and product design. As stated by Bassanino et al. (2010), VR enables designers and engineers to create realistic and immersive 3D models that can be viewed and altered in real-time, allowing for collaborative exploration of design options and simulation of various stages of the construction process, all of which help identify design difficulties early on, reduce errors, and speed up the design development process. Sampaio (2018) argues that VR technology can be used to monitor the progress of a construction project from any vantage point, providing an advantage for both workers and observers. Creating walkthrough models for quicker, more direct testing is another application of virtual reality as a visualisation tool for presenting design concepts to clients (Brown & Nahab, 1996). Visualisation also allows us to simulate and track site progress by creating models that depict the views of the building sequence at any given time (Brown et al., 1999).

In order to give users a fulfilling experience when designing, numerous studies have looked into the system's usability, design simplification, and realistic visualisation. Immersive virtual reality systems effectively generate and convey architectural design in a problem with multiple interrelated variables (Schnabel et al., 2007). Virtual reality (VR) and augmented reality (AR) are examples of extended reality (XR), which can be used to visualise designs better and explore options and layouts. The designer can make better decisions about space and form when time and motion are factored into the visualisation (Kalisperis et al., 2002).

Stakeholders can utilise the digital mock-up to conduct necessary testing during meetings, validating any identified concerns. Immersive virtual reality technology, which accurately replicates the sensation of navigating and engaging with the virtual environment as if it were real, makes this possible (Yao, 2010). Virtual reality serves as a platform that enables individuals to perceive, modify and interact with computer systems and extensive volumes of complex data (Aukstakalnis & Blatner, 1992). The study conducted by Bassanino et al. (2010) demonstrates how professionals can anticipate the architectural design and its aesthetic impact prior to the initiation of construction through the utilisation of immersive virtual reality technology, as supported by previous works by Porter (1997) and Fischer (2008).

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Park and Kim (2012) have identified several successful initiatives focusing on visualising virtual reality (VR) in the construction sector, particularly emphasising enhancing safety management. The analysis of accomplished projects reveals the presence of significant challenges in the management process of site safety. Two key issues that require attention are effectively identifying safety risks specific to each activity and timely communication with trade workers. These concerns have been addressed in previous studies by Lee et al. (2008) and Chen and Kamara (2011).

5. BIM-enabled VR

The architectural, engineering and construction (AEC) sectors utilise virtual reality (VR) and building information modelling (BIM) for various purposes. VR is particularly emphasised for its enhanced ability to communicate dimensions and intricate features compared to conventional two-dimensional visualisation (Johansson & Roupe, 2022) and the fundamental aspect of building information modelling (BIM) is generating and manipulating design data. At the same time, the virtual reality elements relate to the visualisation and engagement with these simulated environments. According to Kim and Ko (2019), the use of virtual reality (VR) technology in the assessment, exhibition, and proof-of-concept phases of architectural design offers occupants and architects a superior "roaming experience". The integration of VR into BIM solutions has the potential to boost communication and problem-solving efficiency within collaborative and interactive projects. Additionally, VR may be utilised to handle challenges related to information retrieval and presentation effectively.

Building Information Modelling (BIM) applies to generating and utilising three-dimensional entities that encompass useful property information, specifically the essential data necessary for a practical building project throughout its complete life cycle. A complete life cycle encompasses various stages: designing, planning, construction, operation, and maintenance (Gheisari & Irizarry, 2016; Song et al., 2018). BIM-enabled VR relies on the model, with a particular emphasis on data linkage. The significance of visualisation in Building Information Modelling (BIM) is well acknowledged (Wang et al., 2011), as users can access BIM data and conduct real-time analysis of parameters such as cost and material type by utilising immersive visualisation environments. This enables the development of efficient building designs without needing a physical presence at the construction site. An instance of utilising BIM-enabled VR is facilitating users to transfer building design concepts into a three-dimensional virtual environment. This process eliminated the limitations of examining two-dimensional drawings and enabled users to evaluate the design area effectively.

According to Sampaio (2018), the integration of virtual reality (VR) technology into the design process is a logical progression for building information modelling (BIM), as it has the potential to improve the overall quality of various built environments. Integrating Building Information Modelling (BIM) and Virtual Reality (VR) enables designers and builders to engage in more efficient discussions regarding potential conflicts and design defects before commencing physical construction. The integration of building information modelling (BIM) with virtual reality (VR) technology has the potential to establish a robust system that can effectively replicate various stages of building development, hence promoting the adoption of sustainable design practices (Hatta et al., 2022). According to Zima et al. (2020), using advanced technology can enhance and improve the accuracy of engineering cost estimation (ECE) processes. The advantages of integrating virtual reality and building information modelling, as stated by Sampaio (2018), are concluded in the figure below.

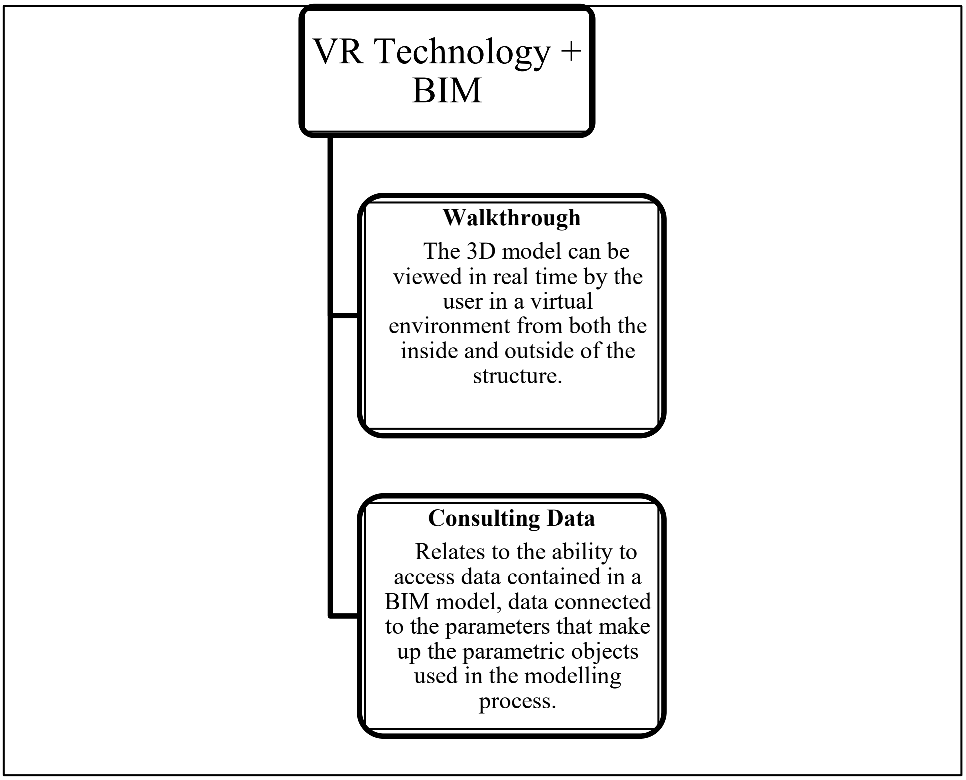

Figure 4. Ways of interaction with 3D/BIM models (Sampaio, 2018).

The integration of building information modelling (BIM) and virtual reality (VR) has been widely recognised for its numerous advantages. However, the challenge lies in effectively transferring data from BIM to rendering engines that support VR, which has hindered the widespread implementation of BIM and VR technologies (Boton, 2018; Wolfartsberger et al., 2018). According to Sampaio (2018), the integration of interactive features of virtual reality into 3D/BIM models during the construction phase enables the virtual testing and rectification of construction projects before their actual implementation. BIM-VR integration has the potential to contribute to cost reduction through the utilisation of real-life mock-ups, hence mitigating the occurrence of expensive errors during on-site operations. Wang (2021) asserts that the integration of BIM and VR technology offers significant advantages in terms of virtual visualisation, information interaction, and management coordination. This combination enables the prediction and dynamic control of potential factors in the construction process, thereby introducing a new paradigm for construction project management. Integrating digital information simulation, building information modelling (BIM), and virtual reality (VR) has emerged as a robust and influential instrument in construction project management.

6. VR-BIM Integration Capabilities

Virtual reality (VR) can be utilised in architecture, engineering, and construction (AEC), serving various purposes such as facilitating collaboration, enhancing project management, and supporting educational endeavours (Pratama & Dossick, 2019; Delgado et al., 2020). Utilising virtual reality (VR) technology within the context of building information modelling (BIM) can enhance several processes. Integrating virtual reality (VR) into building information modelling (BIM) can yield several advantages for the overall design and construction processes. These advantages include enhanced efficiency, improved accuracy, and decreased costs. Moreover, it has the potential to enhance communication among project participants, including workers and stakeholders, thereby creating a more engaging and stimulating experience for all individuals engaged. Building information modelling (BIM) software has consistently been at the forefront of advancements in the architecture, engineering, and construction (AEC) and facility management (FM) sectors since its inception. The primary objective of BIM is to enable the seamless exchange of data among the various disciplines involved in building construction (Carvalho et al., 2021; Porwal & Hewage, 2013; Ren et al., 2021; Scorpio et al., 2022; Xu et al., 2021). The utilisation of real-time data visualisation enables the maintenance of up-to-date BIM models, resulting in enhanced usability and a heightened immersive encounter. The implementation of this approach holds promise in reducing gaps in spatial intelligence, enhancing understanding of projects, and facilitating improved 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).

6.1 Interaction and Collaboration

Virtual reality (VR) has become increasingly popular as a tool for teamwork in the architecture, engineering, and construction (AEC) sector in the last two decades (Asl & Dossick, 2022). This is because VR facilitates improved communication between stakeholders in the construction industry through enhanced design visualisation, improving everyone's understanding of the project (Sampaio, 2018). Virtual reality technology can improve remote teamwork by fostering better participant communication and coordination. This can enhance communication, facilitate better coordination, and reduce mistakes. The intuitive interactions in 3D space and the sense of being in the same room have given rise to Collaborative Virtual Environments (CVEs) in which users are virtually co-located and can interact among each other (Bouchlaghem et al., 2004).

Improvements in collaborative project development can be achieved through interaction with the BIM model to visualise the geometry of the elements and consult the parametric data. Using VR technology to facilitate distant cooperation in a collaborative virtual environment can be helpful for construction project teams (Bouchlaghem et al., 2004). The sole drawback of this technology is that architects and engineers need access to VR equipment and software to make design modifications and assess the consequences of those changes, which can incur substantial costs. Communication and file sharing should be facilitated among team members. This can verify that the building's design is error-free and up-to-date.

Recent studies have also shown that VR has great potential as a tool for making decisions. Virtual reality with multiple users can boost dialogue, comprehension, and teamwork, as Asl and Dossick (2022) note that some VR systems provide for asynchronous collaboration by permitting users to record voice messages while employing the markup tool to draw and explain the system's conflicts and resolutions. These multi-user features facilitate the necessary competence gathering without necessitating a centralised meeting place for all participants. As a result, less time and money will be spent on travelling to the construction site. Virtual reality (VR) interaction and collaboration within building information modelling (BIM) can increase productivity, accuracy, and safety during construction, lowering costs and boosting project quality.

6.2 Costs

It is crucial to assess the expenses associated with integrating VR technology into BIM, ensuring that the advantages, such as enhanced efficiency, cost reductions, and overall project quality, justify the costs. According to Builder Magazine (2018), VR tools can decrease construction costs by up to 90 percent. This is attributed to their ability to provide project owners with realistic depictions of the development, enabling the identification and resolution of potential conflicts or necessary adjustments before the commencement of construction. VR allows for a comprehensive understanding of factors such as room size, presentation style, setup, material options, and budgeting before the actual construction phase, thus preventing reworks during construction and mitigating both cost and time overruns.

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Virtual reality can help reduce the cost of site visits and client meetings by eliminating the need for physical prototypes and mock-ups. By utilising BIM and VR in the AEC industry, teams can reduce the time spent on coordination meetings compared to traditional paper-based processes while increasing satisfaction. Professionals in the fields of architecture, engineering, and construction management have noticed that virtual reality (VR) applications are helping clients to visualise designs better and construction progress earlier, cutting material costs and reducing the number of workers needed for an object. A VR tour can be applied over a BIM model to check, from a facility management perspective, the maintenance schedule (7D/BIM model) or, from a project team perspective, the constructability of the design (Sampaio, 2018). As a result, it is possible to save time and money by holding fewer coordination meetings.

Sampaio (2018) claims that concrete conflicts would arise in the ordinary course of construction, which could lead to extra expenses and delays. With the help of 4D/BIM, the team can analyse any potential conflicts by referring to the BIM model at each stage of construction. Incorporating virtual reality into a building information modelling (BIM) tool can increase the model's capabilities and help cut down on expenses incurred during the construction of real work by reducing the number of costly blunders made by workers on the job site.

7. The potential of VR + BIM to assist the construction industry in Malaysia

Construction site challenges and problems are not confined to Malaysia but have a global impact. Inadequate communication among construction workers and other stakeholders is a fundamental factor contributing to various problems that can hinder productivity and damage a company's reputation. Issues such as cost overruns, time overruns, and safety concerns on the job site often arise from communication shortcomings and need improvement. The implementation of Virtual Reality (VR) technology has the potential to enhance communication among construction workers, professionals, and stakeholders, thereby addressing and alleviating some of these widespread issues.

Integrating Building Information Modelling (BIM) with Virtual Reality (VR) can potentially enhance remote collaboration, fostering improved communication and cooperation among participants. This improvement is anticipated to decrease the probability of errors and misunderstandings throughout the construction process. The application of Virtual Reality (VR) technology in construction has the potential to mitigate the risks of cost and time overruns by enhancing communication among specialists. As time overruns are closely linked to cost overruns, these primary challenges on construction sites predominantly stem from inadequate communication and management among construction workers and stakeholders, resulting in project delays and, inadvertently, increased expenses as costs rise proportionally with the project duration.

In addition, integrating Virtual Reality (VR) and Building Information Modelling (BIM) enhances communication within and outside the AEC industry. Utilising virtual reality (VR) presentations for BIM models in construction projects can revolutionise the industry, transforming how professionals collaborate and interact. By employing VR equipment, users gain a tangible understanding of the BIM model, aiding in the clarification of project structures and minimising confusion. Additionally, project managers can leverage this integrated technology to oversee construction progress remotely without the necessity of a physical presence on-site.

The fusion of VR technology with BIM has a transformative impact on the construction sector, providing immersive experiences and facilitating collaborative efforts at a distance. It enables visualisations on a 1:1 scale, streamlining decision-making processes among stakeholders. This integration simplifies project management procedures and enhances overall project efficiency by allowing a virtual walkthrough of the construction site before commencement. This facilitates optimal planning and refined construction sequencing, reducing delays and increasing productivity, ultimately improving project timelines.

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Unfortunately, a shortage of expertise and funding has hindered the widespread adoption of Building Information Modelling (BIM) in Malaysia, particularly among private construction companies. Although Virtual Reality (VR) technology holds considerable potential for various applications in the construction sector, its integration has not kept pace with BIM. This situation may present challenges in concurrently implementing both technologies in Malaysia. To ensure the successful utilisation of these technologies, it is imperative to enhance the awareness and understanding of BIM and VR among construction professionals and labourers in the country.

The primary barrier to incorporating these technologies arises from a limited understanding and awareness of their benefits to the construction industry. Despite the Malaysian government's introduction of Building Information Modelling (BIM) in 2007, this technology needs to gain widespread adoption, among the industry, particularly private-sector contractors. Moreover, the need for more experience in the construction sector, coupled with the limited dissemination and utilisation of these technologies, makes knowledge transfer challenging. This complexity is further compounded by the insufficient financial resources needed to integrate new technologies into a company, which entails a substantial investment. Additionally, training is imperative to ensure a comprehensive understanding and proficiency in these technologies.

Due to the lagging advancement of BIM in Malaysia, implementing recently integrated technologies, including extended reality technologies like virtual and augmented reality, would also be hindered. To successfully integrate these emerging technologies into the construction sector in Malaysia, it is essential to conduct a thorough study to build trust among contractors in Malaysia, encouraging them to deploy and embrace these technologies inside their organisations. A future study should be undertaken to assess the comprehension and expertise of contractors in Malaysia about the incorporation of BIM and VR technologies. The issues discussed are shown in the theoretical framework illustrated in the figure below.

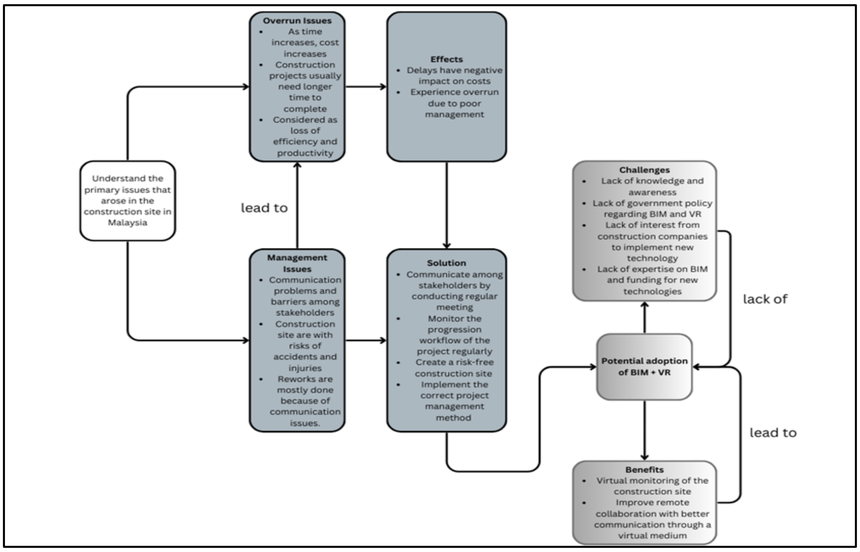

Figure 5. Theoretical Framework of the Potential Adoption of BIM + VR

As shown in the framework in Figure 5 above, the main challenges to potential adoption are a lack of knowledge and awareness, a lack of government policy regarding the technology, a lack of interest among construction companies, and a lack of expertise and funding. These challenges are mainly causing the slow adoption of BIM in Malaysia, thus slowing the adoption of merged technologies such as BIM and VR in Malaysia. Thus, to

foresee these challenges, widespread knowledge of these technologies and their benefits to the construction industry should be widely known by industry experts, including contractors and consultants.
In addition, several research studies suggest that integrating BIM-VR benefits the Architecture, Engineering, and Construction (AEC) industry. It allows for virtual monitoring of construction sites and facilitates enhanced remote collaboration through improved communication in a virtual environment. Nevertheless, these advantages represent only a fraction of the potential benefits of integrating these technologies. Therefore, comprehensive research is still necessary to determine the long-term advantages of BIM-VR integration for the construction industry. With the benefits of this integration well-known to the industry's key players, the adoption of BIM and VR integration will be vast in the Malaysian construction industry.

8. Conclusion

This study conducted a comprehensive literature review of the challenges experienced by Malaysian construction and their potential solutions using virtual reality (VR) integration with building information modelling (BIM). A literature review is the only method used in this study, and it is restricted to studies that already exist in the field. The research did not involve using questionnaires or interviews to gather experts' thoughts. The following is an overview of the study's findings.

Implementing VR and BIM on construction sites can effectively mitigate numerous challenges the construction sector faces, including communication concerns, safety management issues, and time and cost overruns. These integrated technologies are specifically designed to address and manage these issues. For instance, communication problems can be resolved and diminished by organising remote coordination meetings, as these tools facilitate collaboration and communication, aiding team decision-making. Integrating virtual reality with BIM technology enhances communication and problem-solving capabilities, improving efficiency in interactive and collaborative projects. Virtual reality can significantly impact all stages of the construction process, from pre-construction to post-construction. By using VR, design options and proposals can be assessed in a virtual environment, allowing for identifying and resolving errors, construction challenges, and serviceability issues before commencing physical construction. This proactive approach helps prevent cost overruns and delays.

Despite that, the integration of VR and BIM may have certain constraints since it introduces complexity to the project by necessitating more staff training, expertise in the technologies involved, and implementing more modern equipment. The primary constraint in using these technologies in the construction industry is cost, as they necessitate specialised equipment. Hence, a substantial allocation of funds is required to implement this initiative effectively within Malaysia's construction sector. Therefore, it is recommended to prioritise introducing these technologies to Grade 7 (G7) contractors in Malaysia, as they possess more significant capital to adopt these technologies for their construction projects than other construction companies.

There may be obstacles to combining virtual reality and building information modelling (BIM), mainly due to the need for more knowledge on the benefits of these technologies. However, many tools and resources are available to help construction professionals work around these problems. As VR and BIM technology advance and become more accessible, construction professionals are expected to adopt these technologies in their respective companies. Implementing VR and BIM in the construction industry is advantageous for mitigating on-site construction issues in Malaysia. This technology's increasing advancement and availability will inevitably have a more pronounced influence on the construction sector. Adopting VR in BIM practices is crucial for harnessing the full potential of this technology in the construction sector, as this will help overcome the current issues faced by the industry in Malaysia.

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Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

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