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BARRIERS AND SOLUTIONS OF BUILDING INFORMATION MODELLING (BIM) IN CONSTRUCTION SITE SAFETY IN MALAYSIA

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Abstract

The construction industry faces a high fatality rate due to its hazardous work environment and the inherent risks associated with construction activities. These challenges results in numerous incidents, injuries, and illnesses among workers, highlighting the urgent need for enhanced safety measures. Building Information Modelling (BIM) has shown considerable promise in improving safety on construction sites. This study explores the challenges of adopting BIM for construction site safety and suggests potential solutions within the Klang Valley, Malaysia. A questionnaire survey was conducted to evaluate ten major barriers and ten corresponding solutions to BIM adoption. The survey targeted 250 construction professionals with BIM experience, and the collected data were analysed using descriptive statistics in SPSS Version 27. The findings identified interoperability limitations, resistance to change, and lack of knowledge and skills as the primary barriers to adopting BIM for construction site safety. On the other hand, appointing a BIM Safety Manager or Coordinator, integrating BIM with real-time monitoring technology, and enhancing safety planning and visualisation through BIM were identified as the top solutions for implementing BIM in building projects within the Klang Valley.

Keywords: BIM, Barriers, Solutions, Site Safety, Building Projects

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INTRODUCTION

Construction site safety can be enhanced by adopting Building Information Modelling (BIM). However, several barriers continue to impede its widespread implementation. BIM technology enables the adoption of safety protocols during the planning and building phases, yielding benefits such as identifying spatial conflicts, evaluating project hazards, and supplying parametric data throughout a building's life cycle (Rodrigues et al., 2022; Alaloul et al., 2023). Nevertheless, insufficient experience, massive costs for implementation, and change opposition generally prevent its widespread adoption. Integration of BIM with Geographic Information Systems (GIS) and construction scheduling elevates safety hazard identification across project stages.

BIM offers visualization tools aid in identifying safety requirements, standardizing measures, and integrating procedures into project timelines (Ismail, 2023). Safety planning and administration are improved by BIM's 4D, modelling (Doroshin et al., 2023). The use of spatial-temporal data in BIM increases hazard avoidance, site layouts, and safety communication (Ghaffarianhoseini et al., 2017). Construction sites frequently report incidents, illnesses, and injuries, with the industry recording the highest injury rates among industries (Afzal et al., 2021). Data from the Social Security Organisation (SOCSO) indicates that the construction sector's fatality rate is over three times higher than those in manufacturing, mining, and quarrying (Halim et al., 2020). Furthermore, The Malaysian Department of Occupational Safety and Health (DOSH) reported that more than half of the 141 fatalities in 2023 were in construction and manufacturing.

Although BIM has shown promise in improving site safety, limited expertise, high implementation costs, and reluctance to change frequently preclude its widespread use. Despite these challenges, BIM offers opportunities to improve safety practices, foster a positive safety culture, and mitigate risks through enhanced planning, visualisation, and management tools. This paper explores the barriers to BIM adoption in construction site safety and proposes potential solutions for its effective implementation in building projects.

LITERATURE REVIEW

Overview of BIM for construction site safety

Safety in construction is a critical factor influencing overall productivity. Working on construction sites is hazardous, making it one of the most injury-prone jobs (Venkatesh & Ergan, 2023). BIM is utilised to improve construction site safety through better design techniques and work method statements (Azhar & Behringer, 2013). BIM is essential to site safety, minimizing occupational accidents, and improving project management efficiency (Rodrigues et al., 2022). Advanced technology and design modifications help prevent construction accidents. By providing effective platform for proactive safety design, BIM helps mitigate potential future hazards (Shukri et al., 2023:Afzal et al., 2021).

BIM offers various definitions depending on the observer's perspective and the organisation's goals (Golizadah et al., 2023). According to (Malekitabar et al., 2016) and Afzal et al. (2021), pairing BIM with other visualisation tools during the design phase is critical for discovering, analysing, and minimising safety concerns. Similarly, clients, consultants, and contractors may easily collaborate using BIM's integrated virtual model of facility elements, disciplines, and systems (Abed et al., 2019). Moreover, BIM enhances building designs by integrating extensive information, including safety management (Shukri et al., 2023). Despite government attempts to promote BIM, several organisations endure to fully use BIM throughout all project phases (Al-Ashmori et al., 2020) The constantly shifting BIM process provides information-rich models that support all project phases.

Barriers to the adoption of BIM in construction site safety
Resistance to change

Zahrizan et al. (2014) noted that some organizations unwilling to adapt their business processes owing to cost and risk concerns. Due to a lack of managerial skills with technological change, personnel often contend technology will replace their duties, resulting in anxiety when new systems arrive. Implementing BIM often requires hiring specialists to manage and operate the software, which can discourage organization from embracing it (Memon et al., 2014).

High cost

Memon et al. (2014) highlighted that adopting BIM requires substantial initial investments in employee training, technological upgrades, and software updates. Small construction enterprises are often hesitant to adopt BIM due to the significant costs associated with acquiring BIM-based solutions (Rafindadi et al., 2020). According to Othman et al. (2021), BIM's ability to decrease money and time is still unclear, discouraging construction companies from adopting it.

Lack of Knowledge and Skills

In Malaysia, many Small and Medium-Sized Enterprise (SME) construction firms are reluctant to adopt BIM due to their limited capability to implement it in projects (Rafindadi et al., 2020). Furthermore, construction personnel often lack BIM understanding and knowledge (Haron et al., 2017). This knowledge gap is visible as 10.8% of public and private sector respondents were uncertain once their organisations employed BIM (Othman et al., 2021).

Time Required in Training Personal
According to the Criminale and Langar (2017), staff training time is a key obstacle to adopting BIM. Additionally, construction companies must allocate a substantial time and resources to running the training programs (Haron et al., 2017). Rafindadi et al. (2020) noted that the learning process requires both training and considerable time, which increases organizational expenses and effort in mastering new software.

Lack of BIM Contract Documents
Lack of BIM-specific contract agreements and paperwork makes project operations unpredictable and decreases effort to document participant roles. Standard contracts to promote risk distribution and combine dispute resolution, risk compensation, and insurance are lacking (Eadie et al., 2013).

Insufficient External Motivation
BIM adoption depends on external motivation (Ding et al., 2015). Malaysia's BIM incentive systems are inadequate, and construction stakeholders generally lack sufficient motivation to embrace BIM (Cao et al., 2017) This absence of external assistance might make BIM adoption less appealing.

Lack of Standardized Procedures for Work Collaboration
Collaboration with external team members is difficult without standardised methods (Shen et al., 2010). BIM integration with subcontractors is complicated by the construction industry's division (Ku & Taiebat, 2011). Third parties' refusal to share the contractor's BIM model typically causes this issue. Failure to innovate and industry self-interest can also cause data interchange issues (Porwal & Hewage, 2013).

Limitation on Interoperability
Interoperability challenges develop between construction professionals, software, and shared data. Modern BIM tools struggle to integrate various construction businesses during early design (Forgues et al., 2012). Most of the software is developed by a single organisation, thus not all construction team members comprehend it (Anker Jensen & Ingi Jóhannesson, 2013).

Difficulty in Adapting to the BIM Process
Elmualim and Gilder (2014) noted that adapting to BIM technology and processes is a major impediment to BIM adoption in building projects. Stakeholders, particularly in developing markets, face substantial challenges in reengineering existing processes, which greatly hinders the effective implementation of BIM (Yan & Demian, 2008).

Lack of BIM Standards
Lack of government-mandated BIM rules hinders implementation (Li et al., 2018). Adopting BIM requires clear standards for its procedures, activities, and deliverables. Government agencies have established BIM guidelines in recent years, although their coverage is restricted compared to the US, Australia, and other OECD nations.

The solution for implementing BIM in a building project
Support from the Government
BIM adoption is driven by government funding and assistance, enabling Architecture, Engineering, and Construction (AEC) businesses encompass training, consultation, and software and hardware costs (Rafindadi et al., 2020). In order to encourage wider BIM adoption, the government could subsidize BIM software licenses and offer incentives such as free training for companies implementing BIM in their projects (Zambri et al., 2021). For instance, the Malaysian government requires BIM for all public projects exceeding RM 100 million (Rafindadi et al., 2020).

Promote Safety in BIM Training Program
Staff safety training ought to start immediately, best before the project begins, using BIM-based tools or other easily accessible ways (Rafindadi et al., 2020). Events like seminars and workshops may be organised by the government to increase awareness and motivate industry players. Malaysian higher education institutions ought to provide BIM courses that prepare graduates for BIM implementation (Haron et al., 2017).

Provide a National Standard Guidelines
A standardized BIM code of regulations and guidelines is essential for unifying project outputs, facilitating effective communication, and ensuring seamless integration among stakeholders, thereby simplifying deployment and management (Haron et al., 2017). Zambri et al. (2021) highlight the need for the government to establish a national BIM guideline encompassing the entire project lifecycle, including planning, design, construction, and defect liability.

Appoint a BIM Safety Manager or Coordinator
Assign a BIM Safety Manager or Coordinator to monitor BIM-related operations, ensure compliance with BIM standards, and foster communication among stakeholders (Borrmann et al., 2018). This expert is vital for integrating BIM with construction safety management throughout the project to resolve safety concerns using BIM technologies. It allows the project team to identify and minimise safety issues using BIM (Garzia & Lombardi, 2018).

Define Roles and Responsibilities for BIM-Based Safety Management
Define team members' BIM-based safety management responsibilities, including hazard identification, risk assessment, and safety planning. Designating roles helps project stakeholders including the BIM Manager, BIM Coordinator, Model Manager, Information Manager, and BIM Facilitator work together to identify and minimise safety concerns (Akram et al., 2022).

Develop BIM-Based Safety Analytics and Reporting
Leveraging Building Information Modelling's data-rich capabilities, BIM-based safety analytics and reporting monitors, analyses, and reports on construction project safety (Dadashi Haji et al., 2023).Construction projects may create complete safety reports and dashboards using BIM and real-time data from wearable devices, sensors, and site cameras (Dadashi Haji et al., 2023). Consequently, it enhances overall site safety performance while minimizing the risk of accidents (Hire et al., 2024).

Utilize BIM for Automated Safety Rule Checking
Using BIM to automate safety hazard detection and rule-based safety inspections to reduce risk as well as to identify dangers and assure safety compliance before construction (Gao & Chen, 2017). The 2010 Georgia Institute of Technology safety-checking system emphasizes early danger identification using BIM models with safety-specific data including construction equipment, access points, and materials (Hossain & Ahmed, 2022). Integrating BIM with automated safety systems streamlines safety management, enhances decision-making, and foster a safer work environment on construction sites (Hossain & Ahmed, 2022).

Enhance Safety Planning and Visualization with BIM
BIM technology lets project teams produce 3D visualisations of temporary structures, traffic routes, and material storage facilities. This helps identify bottlenecks, congestion, and layout problems, enabling safer solutions (Akram et al., 2022). BIM also facilitates the strategic placement of safety equipment, such as guardrails, safety nets, and personal protective equipment (PPE), through virtual simulations. This method provides educated decision-making and incorporation of safety measures into the building site plan. This makes workplaces safer and lowers accidents (Wettewa & Hadikusumo, 2023).

Integrate BIM with Safety Risk Management Processes
BIM detects, analyses, and reduces project dangers. This connection offers precise 3D models with safety-specific data on building materials, equipment, and access points for early hazard detection and risk mitigation (Chatzimichailidou & Ma, 2022). Incorporating BIM into safety risk

management processes allows construction projects to proactively address safety hazards, ensure compliance with health and safety regulations, and foster a safety-conscious culture among stakeholders (Zou et al., 2017).

Integrate BIM with Real-Time Monitoring Technologies
Integrate real-time monitoring technologies, such as wearable devices and sensors, with BIM to track and analyse safety-related data on-site (Devaiah & Keshav, 2022). By comparing real-time data from these monitoring technologies with the BIM model, teams can accurately track construction progress, identify deviations from the plan, and make timely, informed decisions to address emerging issues. Additionally, overlaying real-time data onto the BIM model enhances visualization of construction progress, fostering improved collaboration and communication among stakeholders (ElQasaby et al., 2022).

RESEARCH METHODOLOGY

This research explores the challenges hindering the adoption of BIM to enhance construction site safety and examines possible solutions, focusing specifically on building projects within the Klang Valley. A quantitative research methodology was utilized, incorporating a questionnaire-based survey to fulfil the objectives of the study. The survey was conducted between January and April 2024, and the survey gathered responses from 250 professionals in the construction industry with BIM experience. The questionnaire was divided into demographic details, barriers to BIM implementation in construction site safety, and potential strategies for overcoming these barriers. The second and third sections featured ten items each, assessing challenges and suggested solutions, with responses gauged on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The collected data were analysed using descriptive statistical methods via SPSS Version 27, and the findings were systematically ranked and presented.

ANALYSIS AND DISCUSSION

Demographic profile

Table 1 summarises the demographic characteristics of the respondents. Among the participants, 62.4% are male and 37.6% are female. The age distribution is as follows: 25.2% are aged 19-24 years, 34.8% are 25 - 34 years, 27.2% are 35 - 44 years, 12.8% are 45 - 54 years, and 27.2% are over 54 years. Regarding educational qualifications, 3.2% hold a technical certification, 36% have a diploma, 45.2% possess a degree, 15.2% hold a master's degree, and 4% have a PhD. In terms of job roles, 23.2% are Architects, 0.8% are Project Managers, 19.6% are Engineers, 5.6% are Site Planners, 0.8% are Safety and Health Officers, 16% are Site Safety Supervisors, 9.2% are Quantity Surveyors, 21.6% are Site Supervisors, and 3.2% did not specify their roles. Regarding work experience, 4.4% have less than 1 year of experience, 46% have 1 - 5 years, 32%

have 5 - 10 years, 16.8% have 10 - 15 years, and 0.8% have over 15 years of experience.

Table 1: Respondents' Demographic Profile

Items	Description	Frequency	Percentage
Gender	Female	94	376
	Male	156	62.4
Ages	19 – 24 years	63	25.2
	25 – 34 years	87	34.8
	35 – 44 years	68	27.2
	45 – 54 years	32	12.8
	Above 54 years	64	25.2
Qualification	Sijil	8	3.2
	Diploma	90	36.0
	Degree	113	45.2
	Master	38	15.2
	PhD	1	0.4
Position	Architect	58	23.2
	Project Manager	2	0.8
	Engineer	49	19.6
	Site Planner	14	5.6
	Safety and Health Officer	2	0.8
	Site Safety Supervisor	40	16.0
	Quantity Surveyor	23	9.2
	Site Supervisor	54	21.6
	Surveyor	8	3.2
Working Experience	Less than 1 year	11	4.4
	1 – 5 years	115	46.0
	5 – 10 years	80	32.0
	10 – 15 years	42	16.8
	More than 15 years	2	0.8

The barriers to the adoption of BIM in construction site safety

The group factors of "barriers" consist of ten components, namely: (i) limitation on interoperability; (ii) resistance to change; (iii) lack of knowledge and skills; (iv) lack of BIM contract documents; (v) difficulty in adapting to the BIM process; (vi) time required in training personnel; (vii) high cost; (viii) insufficient external motivation; (ix) lack of standardized procedures for work collaboration; and (x) lack of BIM standards. The analysis results, presented in Table 2, report the following mean (M) and standard deviation (SD) values: limitation on interoperability (M = 4.24, SD = 0.692); resistance to change (M = 4.16, SD = 0.691); lack of knowledge and skills (M = 4.14, SD = 0.689); lack of BIM contract documents (M = 4.13, SD = 0.724); difficulty in adapting to the BIM process (M = 4.08, SD = 0.782); time required in training personnel (M = 4.07, SD = 0.783); high cost (M = 4.02, SD = 0.816); insufficient external motivation (M = 4.02, SD = 0.556); lack of standardized procedures for work collaboration

(M = 3.88, SD = 0.762); and lack of BIM standards (M = 3.79, SD = 0.699). The average mean value is 4.05, indicating that all barriers are significant. Additionally, the standard deviation (SD) values are below 1.000 for all components, reflecting minimal variability in respondents' perceptions.

Table 2: The barriers to the adoption of BIM in construction site safety

Descriptive Statistic	N	Mean	Std. Deviation
Limitation on Interoperability	250	4.24	0.692
Resistance to change	250	4.16	0.691
Lack of Knowledge and Skills	250	4.14	0.689
Lack of BIM Contract Documents	250	4.13	0.724
Difficulty in Adapting to the BIM Process	250	4.08	0.782
Time Required in Training Personal	250	4.07	0.783
High Cost	250	4.02	0.816
Insufficient External Motivation	250	4.02	0.556
Lack of Standardized Procedures for Work Collaboration	250	3.88	0.762
Lack of BIM Standards	250	3.79	0.699

Based on the data analysis in Table 2, only three (3) main barriers will be discussed. The following are the three (3) primary barriers to BIM adoption for construction site safety in building projects.

Limitation on Interoperability

The most significant challenge in the implementation of BIM for construction site safety in building projects in Klang Valley is the limitation on interoperability. The mean value 4.24 indicates that majority of respondents believe that limitation in interoperability is the primary barrier to implementing BIM for construction site safety. Respondents noted that organizations employ diverse software systems, which make communicating with construction stakeholders complicated. This absence of smooth data transmission might lead to insufficient or erroneous data, decreasing safety planning and risk reduction.

Resistance to Change

Many construction organisations are reluctant to change their business processes related to expense and risk. Fears include technology replacing their jobs. The respondent stated that BIM necessitates substantial modifications to work processes, which can be difficult for certain individuals and organisations to adjust to. Construction organisations may favour simpler, more known procedures over a sophisticated system.

Lack of knowledge and skills

Lack of knowledge and skills ranks as the third highest barrier. BIM software is complex and requires knowledge. These instruments might overwhelm construction professionals without the right knowledge and abilities. The respondents stated building companies may oppose BIM since they are used to traditional ways. Fear of change or desire for familiarity may cause this reluctance.

The solutions for implementing BIM in a building project

The solutions for implementing BIM in building projects encompass ten key strategies: (i) appointing a BIM Safety Manager or Coordinator; (ii) integrating BIM with real-time monitoring technologies; (iii) enhancing safety planning and visualization with BIM; (iv) utilizing BIM for automated safety rule checking; (v) providing national standard guidelines; (vi) ensuring government support; (vii) defining roles and responsibilities for BIM-based safety management; (viii) promoting safety in BIM training programs; (ix) integrating BIM with safety risk management processes; and (xii) developing BIM-based safety analytics and reporting. The analysis results, presented in Table 3, report the following mean (M) and standard deviation (SD) values: appointing a BIM Safety Manager or Coordinator (M = 4.36, SD = 0.749); integrating BIM with real-time monitoring technologies (M = 4.33, SD = 0.754); enhancing safety planning and visualization with BIM (M = 4.33, SD = 0.710); utilizing BIM for automated safety rule checking (M = 4.31, SD = 0.796); providing national standard guidelines (M = 4.31, SD = 0.785); ensuring support from the government (M = 4.31, SD = 0.748); defining roles and responsibilities for BIM-based safety management (M = 4.23, SD = 0.623); promoting safety in BIM training programs (M = 3.99, SD = 0.591); integrating BIM with safety risk management processes (M = 3.80, SD = 0.687); and developing BIM-based safety analytics and reporting (M = 3.73, SD = 0.611).The average mean value is 4.14, suggesting that the proposed solutions are widely regarded as effective. Furthermore, all standard deviation (SD) values are below 1.000, indicating consistency in respondents' views on these solutions.

Table 3: The Solution for implementing BIM in a building project

Descriptive Statistic	N	Mean	Std. Deviation
Appoint a BIM Safety Manager or Coordinator	250	4.36	0.749
Integrate BIM with Real-Time Monitoring Technologies	250	4.33	0.754
Enhance Safety Planning and Visualization with BIM	250	4.33	0.710
Utilize BIM for Automated Safety Rule Checking	250	4.31	0.796
Provide a National Standard Guidelines	250	4.31	0.785
Support from the Government	250	4.31	0.748
Define Roles and Responsibilities for BIM-Based Safety Management	250	4.23	0.623
Promote Safety in BIM Training Program	250	3.99	0.591

Descriptive Statistic	N	Mean	Std. Deviation
Integrate BIM with Safety Risk Management Processes	250	3.80	0.687
Develop BIM-Based Safety Analytics and Reporting	250	3.73	0.611

From the data analysis in Table 3, three (3) main solutions have been identified for discussion. These are the primary strategies for BIM adoption to enhance construction site safety in building projects.

Appoint a BIM Safety Manager or Coordinator
Respondents indicated that the BIM Safety Manager or Coordinator is responsible for overseeing the application of BIM to identify, analyse, and mitigate safety hazards. These professionals ensure seamless real-time communication between the virtual models and the construction site, ensuring that safety measures are effectively integrated and consistently implemented throughout the construction process.

BIM with Real-Time Monitoring Technologies.
Respondents noted that BIM's predictive capabilities and real-time data allow construction teams to rapidly detect and mitigate problems before accidents. Real-time monitoring alerts of structural instabilities and equipment failures.

Enhance Safety Planning and Visualization with BIM
Respondents highlighted that BIM helps to enable comprehensive and thorough safety studies both before and during building. Early in the project life, BIM helps to foresee and minimise safety hazards, therefore improving general project efficiency and ensuring greater safety compliance.

CONCLUSION

The construction industry is known for its elevated rate of fatalities, mostly attributable to the hazardous work environment and inherent dangers associated with the profession. Construction site workers are involved in a lot of accidents, illnesses, and injuries. The findings revealed that interoperability limitations, resistance to change, and lack of knowledge and skills are the primary barriers to BIM adoption for construction site safety. The top solutions were hiring a BIM safety manager or coordinator, integrating BIM with real-time monitoring, and improving safety planning and visualisation. Future studies needs to concentrate on these areas, particularly BIM applications in facility management, to strengthen this research. Expanding the survey to include non-Klang Valley respondents would offer a more complete picture of the building sector. Addressing these difficulties and applying the suggested techniques would help the industry maximise BIM's safety benefits on building projects.

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