MANAGING CRITICAL RISKS IN INDUSTRIALISED BUILDING SYSTEM (IBS) PROJECTS THROUGH BIM FEATURES: A QUANTITATIVE ANALYSIS FROM INDUSTRY PRACTITIONERS IN MALAYSIA

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Graphical abstract
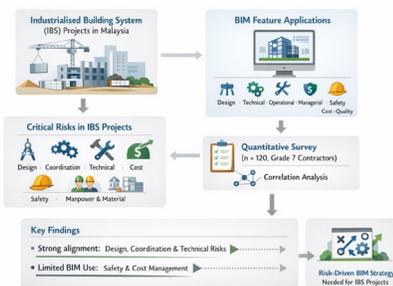
Abstract

The Industrialised Building System (IBS) has been widely promoted in Malaysia to enhance construction productivity, quality, and sustainability. Despite its advantages, IBS projects continue to face persistent risks, particularly those related to design, coordination, and technical implementation. Building Information Modelling (BIM) is often recognised as a strategic tool for managing such risks; however, its application in IBS projects remains selective and uneven. This study examines the relationship between critical risk categories in IBS projects and the application of BIM features based on quantitative data collected from Grade 7 contractors operating in Kuala Lumpur, Malaysia. A structured questionnaire survey was employed, and the data were analysed using descriptive statistics and correlation analysis. The findings reveal that design, coordination, and technical risks are perceived as the most critical risks in IBS projects, while BIM applications are mainly concentrated in technical, operational, and design-related functions. Although strong associations were identified between certain risk categories and corresponding BIM features, the use of BIM for safety and cost management remains relatively limited. These findings suggest that current BIM practices are not yet fully aligned with the overall risk profile of IBS projects. This study provides empirical evidence on the role of BIM as a risk mitigation enabler and highlights the need for a more structured, risk-driven BIM implementation strategy to improve the effectiveness and resilience of IBS project delivery in Malaysia.

Keywords: Industrialized building system (IBS), building information modelling (BIM), risk management, construction technology adoption, Malaysian construction industry.

1.0 INTRODUCTION

In recent years, Malaysia's construction industry has increasingly embraced the Industrialised Building System (IBS) as a strategic approach to enhance productivity, quality, and sustainability. IBS refers to a construction method in which building components are manufactured in a controlled environment, either on- or off-site, and subsequently transported and assembled at the construction site. Compared to conventional construction practices, IBS offers notable advantages, including reduced dependency on manual labour, improved quality control, shorter construction periods, and cleaner site environments. As such, IBS has been actively promoted by the Malaysian government through various policies, incentives, and implementation roadmaps to modernise the national construction sector.

Despite these advantages and continuous institutional support, IBS projects in Malaysia continue to encounter persistent and recurring risks. Unlike conventional construction, IBS projects rely heavily on early-stage planning, precise design coordination, and seamless integration between off-site fabrication and on-site assembly. Any deficiencies during the design or coordination stages may propagate throughout the project lifecycle, resulting in delays, rework, cost overruns, and compromised safety performance (Nik

Mazlan et al., 2025; Feng et al., 2023; Abkar et al., 2024). Previous studies have consistently highlighted that design inconsistencies, coordination failures, technical incompatibilities, workforce capability issues, safety concerns, and cost-related uncertainties remain among the most critical challenges affecting IBS project delivery in Malaysia and other developing construction contexts (Ang et al., 2022; Bernabe et al., 2023).

In parallel with the adoption of IBS, Building Information Modelling (BIM) has emerged as a key digital innovation within the construction industry. BIM enables the creation and management of integrated digital representations of physical and functional building characteristics, supporting decision-making across the project lifecycle. Numerous studies have demonstrated BIM's potential in enhancing design accuracy, improving interdisciplinary coordination, facilitating construction planning, and reducing project risks through functionalities such as 3D modelling, clash detection, 4D scheduling, and 5D cost integration (Ismail et al., 2021; Li, 2021; Wang et al., 2024). Within IBS projects, BIM is often regarded as particularly valuable due to its ability to visualise prefabricated components, simulate assembly processes, and improve communication among multiple stakeholders (Chengbin et al., 2020; Herzanita et al., 2022).

However, despite its recognised capabilities, BIM adoption in Malaysia remains uneven and selective (Anaç et al., 2023; Erdenekhuu et al., 2022; Jamalluddin et al., 2022a, 2022b).. In practice, BIM applications are predominantly concentrated in the design and visualisation stages, while its use for safety management, cost control, and holistic risk mitigation remains limited. More importantly, existing studies frequently discuss BIM adoption in a general sense, without explicitly examining how specific BIM features are aligned with particular risk categories inherent in IBS projects requirements (Moshtaghian & Noorzai, 2023; Abd Jalil & Shaari, 2022; Jalil et al., 2017). Consequently, while BIM is often presented as a solution for managing construction risks, there is limited empirical evidence demonstrating whether current BIM practices effectively address the most critical risks faced by IBS projects in the Malaysian construction industry. Table 1 show the critical risks in IBS projects and relevant BIM features for mitigation.

Furthermore, although prior research has identified various categories of risks associated with IBS implementation, the relative significance of these risks and their relationship with BIM feature applications remain insufficiently explored from the perspective of industry practitioners. The assumption that BIM adoption alone can mitigate IBS-related risks may therefore be premature, particularly if BIM features are not strategically deployed in response to the actual risk priorities encountered on site. This gap highlights the need for a more nuanced, risk-driven examination of BIM utilisation within the IBS project environment.

In response to these issues, this study aims to investigate the relationship between critical risk categories in IBS projects and the application of BIM features as risk mitigation strategies, based on empirical evidence gathered from Grade 7 contractors operating in Kuala Lumpur, Malaysia. By quantitatively analysing practitioners' perceptions of risk significance and BIM usage patterns, this research seeks to determine whether current BIM applications are aligned with the critical risk profile of IBS projects. The findings are expected to contribute to a clearer understanding of BIM's practical role in IBS risk management and to provide insights for policymakers and industry stakeholders seeking to strengthen the strategic integration of digital technologies in Malaysia's IBS-driven construction development.

Table 1 Critical Risks in IBS Projects and Relevant BIM Features for Mitigation

Critical Risk in IBS Projects	Description	Relevant BIM Features for Mitigation	References
Design inconsistencies	Drawing errors or mismatches that lead to component incompatibility	3D modelling, clash detection, design coordination	Nik Mazlan et al., 2025; Feng et al., 2023; Abkar et al., 2024; Chengbin et al., 2020
Coordination failures	Miscommunication between off-site and on-site teams	4D scheduling, collaborative platforms, integrated project delivery	Feng et al., 2023; Ang et al., 2022; Herzanita et al., 2022
Technical errors	Inaccurate shop drawings, material mismatches, poor logistics planning	Structural simulation, automated quantity take-off (5D BIM	Ang et al., 2022; Bernabe et al., 2023; Anaç et al., 2023
Skill shortages	Limited availability of trained workers for IBS assembly	Virtual assembly simulation, BIM-based training modules	Bernabe et al., 2023; Jamalluddin et al., 2022b
Safety risks	Incidents caused by lack of familiarity with assembly or time pressure	Safety simulation, 4D sequencing for hazard detection	Jamalluddin et al., 2022b; Moshtaghian & Noorzai, 2023

2.0 METHODOLOGY

This study adopted a quantitative descriptive-correlational research design to investigate the relationship between critical risks in Industrialized Building System (IBS) projects and the application of Building Information Modelling (BIM) features. A quantitative correlational approach is appropriate for this study as it enables the examination of statistical relationships between predefined constructs without manipulating the research environment, which is consistent with previous construction management and BIM-related studies. A structured questionnaire was developed and administered to Grade 7 contractors based in Kuala Lumpur, Malaysia, identified through the national MyBIM database provided by the Construction Industry Development Board (CIDB). The data collection was conducted on December 2024.

2.1   Questionnaire Structure and Validation

The final questionnaire consisted of three structured sections. A quantitative correlational approach is appropriate for this study as it enables the examination of statistical relationships between predefined constructs without manipulating the research environment, which is consistent with previous construction management and BIM-related studies. Section A collected demographic data from the respondents, Section B assessed their perceptions on the significance of critical risks in IBS projects, and Section C evaluated the strategies and frequency of BIM feature applications in managing those risks. Each item in Sections B and C was measured using a five-point Likert scale ranging from 1 ("Very Low") to 5 ("Very High"). The five-point Likert scale was selected as it is widely used in construction management research to capture practitioners' perceptions and to facilitate statistical analysis, including correlation testing.

To ensure instrument validity, content validation was carried out by a panel of six experts; three academic researchers specializing in construction management and three BIM practitioners with experience in refurbishment and IBS projects. The involvement of both academic experts and industry practitioners helped to ensure that the questionnaire items were theoretically sound while remaining practical and relevant to real IBS project conditions. These experts reviewed the questionnaire for relevance, clarity, and comprehensiveness. Based on their feedback, minor revisions were made to the wording and item grouping to improve construct clarity and internal coherence.

Additionally, reliability testing was conducted during the pilot phase using Cronbach's alpha analysis. The reliability coefficients for both critical risk items and BIM application items exceeded the threshold of 0.7, indicating acceptable internal consistency. This reliability outcome indicates that the measurement scales used in this study are internally consistent and suitable for further statistical analysis.

2.2   Sampling Procedure and Participants

The study utilized simple random sampling to select participants from the official registry of IBS-certified Grade 7 contractors operating in Kuala Lumpur. Grade 7 contractors were selected as they are typically involved in large-scale and complex construction projects, including IBS developments, and are more likely to have formal exposure to BIM implementation. Based on Krejcie and Morgan's sample size determination table, a minimum of 144 respondents was required for a population of 235. Although the achieved sample size was slightly below the recommended threshold, the number of valid responses obtained is considered adequate for exploratory correlational analysis in construction management studies. However, due to practical constraints and voluntary participation, the final number of valid responses collected was 120.

The questionnaire was distributed via Google Forms, and respondents were provided with clear instructions and assurances of confidentiality and anonymity. Only fully completed submissions were included in the final dataset. Nevertheless, the study acknowledges that the geographical focus on Kuala Lumpur and the emphasis on Grade 7 contractors may limit the generalisability of the findings to smaller contractors or other regions in Malaysia.

2.3   Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical methods. Descriptive statistics, including mean and standard deviation, were used to assess the perceived significance of different types of risks and the extent of BIM feature usage among practitioners. To address the third objective, Pearson's correlation coefficient (r) was computed to examine the relationship between critical risk categories and BIM application strategies. In this study, the correlation analysis was conducted by relating the aggregated mean scores of each risk category with the aggregated mean scores of the corresponding BIM feature categories. The significance level (p-value) was set at 0.05 to determine statistical relevance.

This methodological approach enabled the study to generate reliable, generalizable insights into how BIM is used to manage risks in the Malaysian IBS construction context, providing an empirical foundation for further research and practical policy recommendations. It is important to note that correlation analysis does not imply causation; rather, it indicates the strength and direction of association between perceived risks and BIM feature usage.

3.0 RESULTS AND DISCUSSION

3.1   Respondent Demographics

The respondent profile in Table 2 reflects a technically competent and professionally experienced group of industry practitioners. A total of 67.5% of the respondents were male and 32.5% female, consistent with the gender distribution in Malaysia's construction sector, which remains predominantly male. Most participants were aged between 31 and 40 years (50.0%) and 41 and 41–50 years (30.0%), indicating a mature cohort with significant industry exposure.

In terms of qualifications, the majority held at least a bachelor's degree (69.17%), with 18.33% possessing a master's degree, and a small number holding PhDs (1.67%). This academic background aligns with the technical demands of the study, particularly regarding BIM application and risk assessment.

Table 2 Demographic Profile of Respondent

	Frequency	Percentage
Gender		
Male	81	67.50
Female	39	32.50
Total	**120**	**100%**
Age		
21-30	15	12.50
31-40	60	50.00
41-50	36	30.00
51 and above	9	7.50
Total	**120**	**100%**
Highest Education qualification		
Certificate	0	0
Diploma	13	10.83
Bachelor's Degree	83	69.17
Master's Degree	22	18.33
PhD	2	1.67
Total	**120**	**100%**
Experience in the Construction Industry		
Less than 5 years	27	22.50
6-10 years	28	23.33
11-15 years	32	26.67
More than 15 years	33	27.50
Total	**120**	**100%**
Experience in IBS Construction Projects		
Less than 5 years	84	70.00
6-10 years	31	25.83
11-15 years	2	1.67
More than 15 years	3	2.50
Total	**120**	**100%**
Experience in BIM technology in the project		
Less than 5 years	105	87.5
6-10 years	8	6.67
11-15 years	2	1.67
Total	**120**	**100%**

Similarly, 87.5% of respondents had fewer than five years of BIM experience, reflecting the relatively recent adoption of digital tools in Malaysia. Despite limited exposure, the combination of industry tenure and formal education suggests that the sample is well-positioned to provide informed insights into IBS risk management through BIM integration.

Although the majority of respondents reported less than five years of direct experience with IBS and BIM, this reflects the relatively recent adoption of these systems in the Malaysian construction industry. Similar respondent profiles have been reported in previous studies examining BIM implementation in developing construction contexts.

3.2   Identifying the Most Significant Critical Risks in IBS Projects

The first research objective sought to identify the most significant critical risks affecting IBS project implementation in Malaysia. Descriptive statistical analysis was conducted on seven predefined risk categories using mean scores derived from a five-point Likert scale. The findings show in Table 3, revealed that Design Risk was perceived as the most critical (Mean = 4.477), followed by Coordination Risk (Mean = 4.387)

and Technical Risk (Mean = 4.314). All three were interpreted at the "Very High" level. Other risks such as Cost Risk (Mean = 4.140), Manpower Risk (Mean = 4.150), Material Risk (Mean = 4.123), and Safety and Health Risk (Mean = 4.017) were also rated as "High", but to a lesser degree.

The dominance of design-related risk is particularly significant in the context of IBS, where prefabrication requires a high level of design accuracy and early decision-making. Any design error introduced at the initial stage may propagate across multiple prefabricated components, resulting in costly rework and schedule disruption.

These results are consistent with previous studies highlighting that design inconsistency, poor inter-team coordination, and technical incompatibility are frequent barriers in IBS. Design-related issues are particularly crucial in IBS, where prefabrication demands precision and any error during the design phase can cascade into costly delays during assembly. The high perception of coordination risk underscores the multidisciplinary nature of IBS, which requires seamless integration among architects, engineers, contractors, and suppliers. Similarly, technical risk reflects the industry's struggle to adapt to new systems and technologies, particularly when conventional project management practices are still dominant.

Table 3 Descriptive analysis for most significance critical risk in IBS project

Independent Variables	Mean	Std. Deviation	Mean Value
Design Risk	4.477	0.321	Very High
Technical Risk	4.314	0.293	Very High
Manpower Risk	4.150	0.325	High
Material Risk	4.123	0.414	High
Coordination Risk	4.387	0.320	Very High
Safety and Health risk	4.017	0.399	High
Cost Risk	4.140	0.411	High

The consistency in ranking these risks affirms the industry's shared experience and reinforces the need for more structured risk governance mechanisms in IBS projects.

3.3   Evaluating BIM Features Application Strategies

The second objective of the study focused on assessing how BIM features are applied as strategic tools to mitigate the identified risks in IBS projects.

Respondents evaluated the extent of their use of various BIM applications across eight functional categories. The results in Table 4 showed that Technical (Mean = 4.588), Operational (Mean = 4.563), Managerial (Mean = 4.553), and Design (Mean = 4.486) were the most frequently utilised BIM features, each interpreted as "Very High". Meanwhile, features such as Safety (Mean = 4.128), Quality (Mean = 4.137), Cost (Mean = 4.113),

and Structural (Mean = 4.112) scored slightly lower, though still within the "High" category.

The high utilisation of technical and operational BIM features indicates that practitioners primarily employ BIM to support constructability, visualisation, and coordination-related tasks, which are closely linked to the dominant risks identified in IBS projects.

The high rating for technical and operational BIM applications suggests that the industry recognizes BIM's strength in managing complex construction tasks, particularly those involving prefabricated systems. BIM's capacity to visualize design outcomes, simulate workflows, and optimize scheduling aligns well with the technical requirements of IBS. Managerial features, including communication management and information tracking, are also widely applied, indicating BIM's role beyond design and into overall project administration.

Table 4 Descriptive analysis for BIM features application strategies

Dependent Variables	Mean	Std. Deviation	Mean Value
Cost	4.113	0.334	High
Management	4.553	0.411	Very High
Design	4.486	0.438	Very High
Structural	4.112	0.404	High
Operational	4.563	0.401	Very High
Technical	4.518	0.411	Very High
Safety	4.128	0.311	High
Quality	4.137	0.370	High

However, the relatively lower usage of BIM for safety and cost functions suggests untapped potential. While BIM tools such as 4D and 5D modelling can significantly enhance safety planning and cost estimation, they may be underutilized due to lack of training, resistance to change, or limited software integration on site. These findings highlight an opportunity for further BIM skill development and targeted investment in digital tools aligned with IBS-specific risk profiles.

3.4   Correlation Between Critical Risks and BIM Feature Strategies

The third objective investigated the relationship between the critical risks identified and the BIM features used to mitigate them. Pearson's correlation analysis was employed to determine the strength and significance of associations. The analysis revealed very strong and statistically significant positive correlations between several key risk categories and BIM applications. The strong correlations observed suggest that BIM features are generally applied in areas where practitioners perceive higher levels of risk, indicating a degree of alignment between risk awareness and BIM utilisation strategies. For

example, the exceptionally strong correlation between design risk and design-related BIM features reflects the industry's reliance on BIM for design coordination, clash detection, and constructability assessment in IBS projects. Similarly, the strong association between coordination risk and technical BIM features highlights BIM's role in facilitating interdisciplinary communication and information integration.

Based on Figure 1, the most notable relationship was between Design Risk and BIM Design Feature ($r = 0.985$, $p < 0.001$), indicating that BIM is extensively used to address challenges in the design phase. Similarly, Coordination Risk showed a strong correlation with BIM applications ($r = 0.911$), and Technical Risk also demonstrated a robust relationship ($r = 0.832$), all significant at the 0.001 level.

Other risks such as Material Risk ($r = 0.613$), Cost Risk ($r = 0.656$), and Manpower Risk ($r = 0.524$) also exhibited strong correlations with BIM strategies. The only moderate correlation was observed between Safety and Health Risk and BIM usage ($r = 0.417$), suggesting that BIM is not yet fully embedded into safety planning protocols in the local IBS context.

However, the moderate correlation observed for safety and health risk suggests that BIM has not yet been fully

embedded as a proactive safety management tool in IBS projects. While BIM possesses the capability to support safety planning and hazard identification, its current application appears to be limited by organisational practices rather than technological constraints.
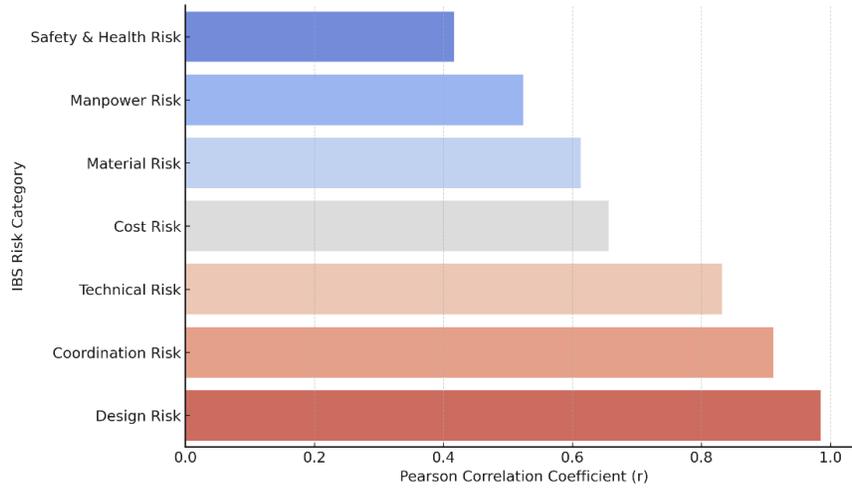

Figure 1 Pearson correlation between IBS risk categories and BIM feature applications.
The strongest relationships were observed between design risk and design-related BIM tools (r = 0.985), followed by coordination risk (r = 0.911) and technical risk (r = 0.832). Moderate correlation was found for safety and health risk (r = 0.417), indicating selective application of BIM in certain domains.

These results validate the hypothesis that BIM is not only a design or visualization tool but also an effective risk mitigation mechanism when deployed strategically. The strength of correlation between design and technical risk with their corresponding BIM features confirms the alignment between perceived needs and digital solutions. However, the weaker correlation in safety planning reflects a gap between BIM's capabilities and its current usage, potentially due to limited awareness, inadequate training, or system incompatibility.

It is important to emphasise that correlation does not imply causation; rather, the findings indicate associative relationships between perceived risk severity and BIM feature usage. These relationships should therefore be interpreted as evidence of alignment patterns rather than direct causal mechanisms.

From a practical standpoint, these findings support the need for capacity building among contractors and project teams to extend BIM usage into safety, cost, and structural risk management. Moreover, they provide empirical justification for policymakers and industry leaders to embed BIM-based risk mitigation protocols into IBS project guidelines.

4.0 CONCLUSION

This study explored how critical risks in Industrialised Building System (IBS) projects can be addressed through the strategic application of Building Information Modelling (BIM) features, focusing on the perspectives of Malaysian industry practitioners. By examining the perceptions of industry practitioners, this study provides empirical insight into the alignment between perceived risk severity and the actual application of BIM features within IBS project environments. The quantitative findings highlight three dominant risk categories which is design, coordination, and technical that remain persistent despite sustained governmental promotion and policy incentives. These findings indicate that risk exposure in IBS projects remains concentrated in early project stages, where design decisions, coordination mechanisms, and technical planning play a critical role in determining overall project performance.

Table 5 Summary of Key Findings and Practical Implications

Key Finding	Implication
Design, coordination & technical risks most critical	Focus risk mitigation efforts during design/pre-construction stage
BIM usage highest in design and technical areas	Prioritise training in early-stage BIM tools
Low BIM use for cost and safety	Encourage 4D/5D BIM adoption via incentive-based policies
Strong correlation between risk and BIM use	Develop risk-driven BIM frameworks for IBS

The analysis revealed that BIM is widely acknowledged by practitioners as a valuable tool for mitigating these risks, particularly in areas of technical coordination, operational planning, and design integration. However, the study also demonstrates that BIM adoption alone does not guarantee effective risk mitigation, particularly when its application is limited to specific project functions rather than embedded as an integrated risk management strategy. Statistically significant positive correlations between specific risk categories and relevant BIM applications indicate an increasing alignment between perceived challenges and the strategic use of digital solutions. Nonetheless, the results also expose a pronounced gap between BIM's full potential and its actual deployment, especially in the domains of safety, cost, and structural risk management. The comparatively lower application of BIM for safety and cost management further suggests that organisational readiness, training, and institutional support play a decisive role in shaping how BIM capabilities are translated into practical risk mitigation outcomes.

Table 5 summarizes the key findings and their practical implications. The persistence of design, coordination, and technical risks underscores the importance of concentrating mitigation measures during the design and pre-construction phases, when the opportunity for error prevention is greatest. The current pattern of high BIM usage in design and technical areas suggests that targeted training in early-stage BIM tools could yield immediate performance gains. Conversely, the low adoption of BIM for cost estimation (5D) and safety simulation (4D) signal the need for incentive-based policies and industry guidelines to expand usage into these underutilised areas. Furthermore, the strong correlation between risk severity and BIM utilisation supports the development of risk-driven BIM frameworks tailored for IBS projects.

From a practical perspective, the findings underscore the need for construction organisations and policymakers to promote a more structured, risk-driven approach to BIM implementation in IBS projects, particularly by strengthening competencies in 4D and 5D BIM applications and integrating digital tools into safety and cost management practices.

Theoretically, this study contributes to the existing body of knowledge by quantitatively mapping the relationships between IBS risk categories and BIM feature applications, moving beyond generic BIM adoption narratives towards a more context-sensitive, risk-informed perspective. Nevertheless, the findings should be interpreted in light of certain limitations, including the focus on Grade 7 contractors in Kuala Lumpur and the reliance on perceptual data, which may limit broader generalisability.

In conclusion, managing risk in IBS projects demands more than technological adoption but it requires the deliberate alignment of digital capabilities, organisational maturity, and workforce competence. As Malaysia's construction sector accelerates its transition towards industrialisation and digitalisation, these findings offer timely insights for policymakers, industry leaders, and researchers seeking to enhance the resilience and efficiency of IBS-driven project delivery. Future studies could extend this research by incorporating longitudinal data, exploring causal relationships between BIM implementation and risk reduction outcomes, or examining IBS projects across different contractor grades and geographical contexts.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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