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USE OF BUILDING INFORMATION MODELLING TO MITIGATE COST OVERRUNS IN DESIGN AND BUILD PROJECTS

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ABSTRACT

Cost overrun in the design and build (D&B) procurement method is a significant obstacle in achieving the project goals. Therefore, it has become critical consideration over its numerous benefits when selecting this procurement method. However, applying new technologies, such as Building Information Modelling (BIM), can significantly minimise this issue. Thus, this study aims to investigate the use of BIM to manage the cost overrun issues in D&B projects. A qualitative approach based on two rounds of interviews was conducted to collect the data. The study findings revealed ten highly important causes of cost overrun in D&B projects. Continuous design and drawings changes due to incomplete initial drawings prepared with insufficient design data at tendering stage, errors or omissions revealed during construction, and inefficient planning and scheduling by the contractor were the top three causes. Further, BIM functions such as interoperability and exchange of information, clash detection, digitalised quantity take off, and cloud computing were identified as they can be used to manage highly important causes of cost overrun in D&B projects. This research assists professionals in identifying the most appropriate BIM functions to reduce the fear of price uncertainty when implementing the D&B procurement method in their projects. Further research on identifying the barriers and suitable strategies for implementing BIM in D&B projects to reduce cost overrun can be based on the present study.

Keywords: *Building Information Modelling (BIM), Causes, Cost overrun, Design and Build projects, BIM Functions.*

1. INTRODUCTION

The design and build (D&B) procurement technique is a project delivery method that assigns the contractor both design and construction responsibility (Ruvinda & Bamunuachchige, 2020). Although the D&B procurement method has various advantages, it can still pose significant risks to contractors if not adequately mitigated through effective risk management (Oztas & Okmen, 2004). Pham et al. (2021) listed several risk factors in D&B projects, such as cost overrun, delays, lack of collaboration

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among the team, complexities in designing, and frequent design changes. Literature suggests that using proper innovative technology to improve the performance of selected procurement can enhance overall productivity and minimise cost overrun risk in construction projects (Borg, 2015). Among various digital technologies, BIM has a higher degree of potential for offering a collaborative platform and is majorly helpful in identifying design clashes and minimising the cost of correction (Bello et al., 2021; Muhammad et al., 2019).

The D&B procurement method is gaining popularity since it gives clients a comparatively higher price certainty than the traditional method (Brahim et al., 2018). However, from the contractor's standpoint, using the lump-sum (fixed price) payment system in D&B necessitates strict cost control measures (Cunningham, 2015). Identifying design clashes, minimising the cost of correction, and maintaining proper information management are all made possible by BIM (Bello et al., 2021), which directly contribute to reducing the contractor's pricing risk in D&B projects.

Even though BIM deployment may be highly beneficial, BIM as a collaborative platform for construction management is still in its infant development stage and has some significant barriers to implementation (Muhammad et al., 2019; Siddiqui et al., 2019). Construction sector's adoption of new technologies is slower than that of other industries (Haupt et al., 2019). Therefore, this research aims to investigate the use of BIM to manage the cost overrun in D&B projects. The objectives of this research are to investigate the important causes of cost overrun in D&B projects, identify common BIM functions used in construction projects, and investigate the suitable BIM functions that can be used to manage each highly important cause.

2. LITERATURE REVIEW

2.1 PRICING RISK IN DESIGN AND BUILD PROJECTS

The separation of design and construction stages is identified as the root cause of some critical issues in construction projects, such as lack of responsibility of both parties, issues in constructability, and increment of variation (Rahmani et al., 2017). Thus, combining those two stages, the notion of D&B was raised to respond to those issues (Adamu et al., 2017). In that case, the D&B contractor is solely responsible for the design and the construction (Ahmed & El-Sayegh, 2020). Consequently, the risk for D&B contractors will significantly rise (Jimenez et al., 2020). This critical amount of risk shifted to the contractor is a major concern for D&B projects. To effectively address this issue contractor shall adequately identify the risks at the earliest phase in D&B projects (Ahmed & El-Sayegh, 2020). Rostiyanti et al. (2019) described pricing risk that arises from greater price uncertainty as a characteristic of D&B projects. The main reasons for pricing risk for D&B contractors are the unavailability of precise employer requirements, design discrepancies, and comprehensive specifications at the time of tender pricing (Rostiyanti et al., 2019; Saaidin et al., 2017). In addition, poor coordination among the project team is also considerably involved in this risk (Pham et al., 2021). Also, errors in taking off, rework due to clashes, problems in constructability, and errors identified during the construction phase are highlighted causes of pricing risk due to contractors' faults (Ogunsanmi et al., 2011; Pham et al., 2021; Ramanathan et al., 2011). Yusoff et al. (2022) stressed that implementing novel technologies could efficiently address most of these issues.

2.2 CONCEPT OF BUILDING INFORMATION MODELLING (BIM)

BIM is the basis for the construction sector's digitalisation (Gilkinson et al., 2015). It is a process or a concept used to successfully develop, manage, and distribute information across the life cycle of a construction project using different tools and technologies (Ahmed & El-Sayegh, 2020). In the construction industry, BIM enables the simulation of construction projects in a virtual environment (Azhar, 2015). The virtual model can be used precisely and efficiently for data extraction, analysis, and processing to make more accurate decisions (Liston, 2008). Literature suggests that 3D visualisation, constructability analysis, and clash detection are the key functions of BIM (Gholizadeh et al., 2018). Additionally, construction planning, cost management, interoperability of information, and digitalised taking off are other commonly discussed functions of BIM (Ganbat et al., 2020). Ultimately, these multiple usages of BIM are gradually increasing the construction industry's productivity and eventually improving its cost-effectiveness.

2.3 USE OF BIM TO MINIMISE PRICING RISK IN D&B PROJECTS

The implication of BIM enables and acknowledges a higher level of interaction between the different elements of the design. Subsequently, when design modifications are made, all relevant elements are automatically updated and disseminated electronically to all project stakeholders (Gad et al., 2022). Frequently this will happen in the earlier phase of the project when the cost of making design modifications is minimal (Gilkinson et al., 2015). Therefore, this process dramatically reduces the cost overrun in construction projects.

In D&B projects, clients prefer lump sum contracts due to the price certainty it offers to the client (Adamu et al., 2017). Conversely, the contractor faces greater price uncertainty when offering lump sum prices in the contract (Adnan et al., 2012). Therefore, D&B contractors should adequately manage the risk to achieve the predetermined financial goals. In that case, the impact of price risk sources, such as poor coordination, poor information flow, discrepancies, and errors, can be decreased by implementing novel technologies that support collaborative working environments with better data accuracy (Braglia et al., 2022). In that scenario, results from different studies suggest that BIM has dramatically reduced cost overruns and promoted price certainty by increasing collaboration and accuracy (Badran et al., 2020; Muhammad et al., 2019). Therefore, successful implementation of BIM in D&B projects may be beneficial for the D&B contractor to tackle price uncertainty in the project systematically. Hence in-depth discussions to identify the synergy between BIM adaptation and mitigating pricing risk in D&B will effectively relieve D&B contractors from the disadvantageous situation. Several types of research are available on the D&B procurement method based on its adaptability (Adamu et al., 2017), contractual and legal background (Gad et al., 2020), and risk management (Ayuningtyas & Rarasati, 2020). Similarly, a tremendous amount of research is available regarding BIM based on various areas, such as new trends (Disney et al., 2021), risks related to BIM adoption (Badran et al., 2020), barriers and strategies for BIM implementation (Olanrewaju et al., 2022), and cost overrun and delay management (Muhammad et al., 2019). Nevertheless, studies to investigate the adoption of BIM in D&B projects are limited (Brahim et al., 2018; Yusoff et al., 2022). Even though there is a high likelihood that using BIM features effectively will produce significant results in pricing risk management in D&B projects, research on this topic from the contractor's perspective is rarely found.

3. RESEARCH METHODOLOGY

This research investigates how BIM can be used to manage cost overrun for pricing in D&B projects. A comprehensive literature review was conducted based on the D&B procurement method and concept of BIM in construction. Those literature findings are required to validate the selected D&B project contexts. Since this research is keen to obtain expert opinion rather than numerical data, the qualitative approach is selected as suitable for the study (Saunders et al., 2019). An interview survey was selected to collect data because it facilitates gaining a holistic view from the selected, experienced, expert interviewees (Döringer, 2021). In addition, semi-structured interviews were used for data collection to acquire flexible and elaborative opinions within the limited time frame (Döringer, 2021). Two rounds of interview surveys were incorporated, considering the requirements of the study, and details were demonstrated in Figure 1.

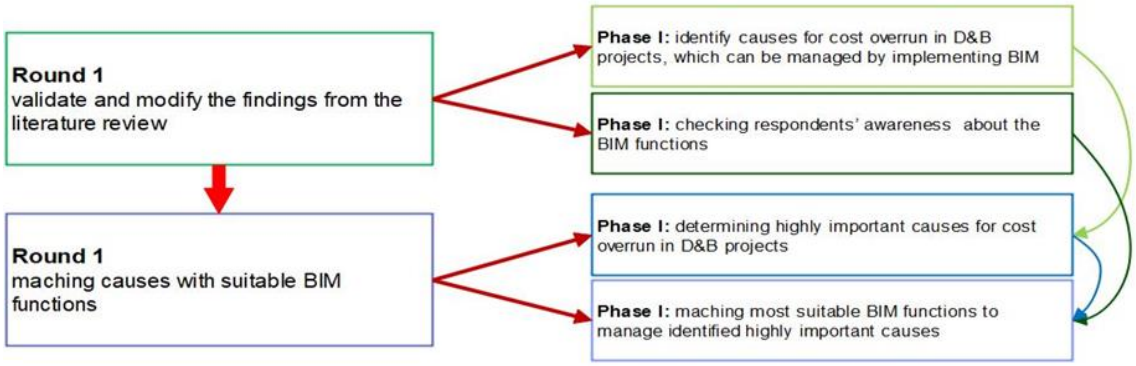

Figure 1: Details of Delphi rounds

Manual content analysis was used to analyse the collected data to generate meaningful outcomes from the textual data (Medelyan, 2020). A Delphi study's effectiveness boosts when conducted with a heterogeneous sample of experts (Skulmoski et al., 2007), so this research adopted a heterogeneous sample. Respondents were selected through purposive sampling as it allows the researcher to choose experts according to the requirements of the study (Campbell et al., 2020). The selected 12 respondents for the study have working experience in the digitalization-built environment from Australia, the United Kingdom, New Zealand, United Arab Emirates, and Sri Lanka. They were selected according to the following criteria, and Table 1 elaborates on the interviewees' profile.

Compulsory criteria (At least one must be satisfied):

- **C1-** At least five years of working experience in the construction industry
- **C2-** Working experience in at least 3 D&B projects
- **C3-** Research experience in D&B procurement method and/or BIM

Additional criteria

- **A1-** Participated in at least three BIM-applied projects
- **A2-** Interest in modern technologies for construction
- **A3-** Completed a postgraduate qualification related to the built environment
- **A4-** Certificate level qualification in BIM

Table 1: Interviewees' profile

Code	Profession	Compulsory Criteria			Additional Criteria			
		C1	C2	C3	A1	A2	A3	A4
I01	Chartered Quantity Surveyor (Consultant)	✓	✓			✓		
I02	BIM Modeler (5D quantity surveyor)	✓		✓		✓		✓
I03	Chartered Quantity Surveyor (BIM practitioner)	✓	✓		✓	✓		
I04	Chartered Quantity Surveyor (BIM practitioner)	✓	✓			✓		
I05	BIM expert (5D BIM lecturer)	✓	✓		✓	✓	✓	✓
I06	Quantity Surveyor (BIM practitioner)	✓		✓		✓		✓
I07	Chartered Quantity Surveyor (Contract manager)	✓	✓		✓	✓		✓
I08	Chartered Quantity Surveyor (BIM practitioner)	✓	✓			✓		
I09	Research Scholar (In digital technology)			✓		✓	✓	
I10	Quantity Surveyor (BIM practitioner)	✓	✓			✓		
I11	Site Quantity Surveyor (In a D&B project)	✓	✓			✓		
I12	Project Manager (In a D&B project)	✓	✓			✓		

4. FINDINGS AND ANALYSIS

4.1 CAUSES FOR COST OVERRUN IN DESIGN AND BUILD PROJECTS

The literature review reveals thirty (30) causes for cost over-run in D&B projects. Even though most identified causes are directly related to D&B projects, few are not specified. Therefore, round 1 phase 1 of the interview survey was used to confirm the applicability of findings to D&B projects, check the possibility of managing them using BIM, and add any new causes. As a result, four (04) new causes were added (indicated in bold text), and nine (09) causes were rejected. Ultimately, twenty-five (25) causes were confirmed from this stage. In the interview round 2 phase 1, respondents were asked to categorise identified causes according to their level of importance as high, medium, and low. Out of the twenty-five (25) identified causes, ten (10) causes were confirmed as highly important causes, with more than 75% agreement from the respondents. Further, another ten causes were identified as moderately important causes while the other five were categorised as less important. Findings are summarised in Table 2.

Table 2: Causes of cost overrun

No.	Item Code	Description	
01	C01	Continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at the tendering stage	**High**
02	C23	Errors or omissions revealed during construction	
03	C19	Inefficient planning and scheduling by the contractor	
04	C21	Inadequate constructability of the design	
05	C17	Inappropriate construction methods followed by contractors	
06	CN01	Lack of clarity in the employer's brief	
07	CN03	Issues relating to D&B are not properly addressed in the Conditions of Contract	
08	C26	Improper geotechnical investigations	

09	C07	Unforeseen weather and site conditions experienced D&B contractor could not have predicted	
10	C25	Poor communication between design and construction teams	
11	C02	Frequent changes in construction drawing during the execution of construction works	**Medium**
12	C05	Delay in revising and approving design documents by consultant or employer	
13	C14	Cash flow problems faced by the contractor due to the delayed payment from the client	
14	C22	Quality control and assurance-related causes	
15	C18	Slowness in decision-making by employer and consultant which cause additional cost for material idling	
16	C30	Mistakes in tender document preparation and misinterpretation of contractual clauses	
17	CN02	Mistakes in communicating the requirements of basic design parameters	
18	C29	Poor material selection and waste management strategies	
19	CN04	The inexperience of client's and/or contractor's project management teams	
20	C11	Lack of materials at the site due to difficulty in extracting exact material quantity from incomplete and unapproved drawings	**Low**
21	C12	Rework due to design clashes, poor and inaccurate identification of employer requirements, and lack of final quality caused by work acceleration	
22	C13	Poor judgement in estimating time and resources due to inadequate experience of the contractor	
23	C03	Mistakes in quantity take off at the time of tender pricing by design and build contractor	
24	C08	Delays in early procurement of the specialist subcontracting work due to incomplete designs and specifications	
25	C15	Additional works required on site conditions and the employer's request	

Experts rejected "dependency on specialist works without alternatives", "shortage of local materials", "insufficient pricing for preliminaries and fewer allocations for contingencies", and "unqualified workforce" as those causes are *not unique to D&B projects*. Further, "environmental issues", "delays in material approval by consultant/employer", and "delays in getting authority approvals" were rejected since those causes *cannot be managed with BIM***.** Additionally, respondents rejected "price fluctuation in materials and fuels" and "catastrophes", reasoning with both above.

Although high constructability is considered a vital benefit of the D&B procurement method, inadequate planning, experience, and expert knowledge in designing and time constraints can be challenging. Due to that, the constructability of the design can be reduced compared to the traditional method. Respondents identify this is a common situation in developing countries because contractors may not have the matured experience dealing with the unique characteristics of D&B projects, which can cause cost overrun. Suggesting "lack of clarity in employer's brief" as a new cause for cost overrun in D&B project I01 stated, "*clients who are unfamiliar with D&B procurement method do not provide sufficient details about their requirements. So, the contractors tend to design the project based on their own experience disregarding the clients' actual requirements"*. Further, I05 suggested "mistakes in communicating the requirements of basic design parameters" is a unique cause for cost overrun in D&B project due to the overlapping of design and construction phases. Another common problem is clients are unable to address the issues adequately, through particular conditions of the contract, because of their lack of knowledge related to the D&B method. Further lack of experience in the contractor's project management team is another factor not discussed in the literature. I10 stated that "*some engaged in D&B projects are not familiar with the*

integrated nature of this method; they are familiar with the traditional method and completely subcontract the design responsibility to another party which is not the ultimate goal of this D&B method". Therefore, additional cost is required for the design and unable to obtain cost-effective opportunities in the D&B method for the contractor.

4.2 FREQUENTLY USED FUNCTIONS OF BIM IN CONSTRUCTION PROJECTS

Thirty-five (35) BIM functions were identified through the literature, and in round 1 phase 2, respondents were asked to highlight any modifications or additions. However, no modifications/new functions were raised. Respondents confirmed that almost all the functions they know were included in the given list.

In round 2 phase 2, respondents were asked to select the five most suitable BIM functions for each highly important cause identified in round 2 phase 1. Out of those thirty-five functions, ten (10) functions were rejected in this stage. The suitable BIM functions were selected to manage the cost overrun in a project's design and construction stages in this study. Therefore, "program area and space validation", "asset management", "record model/ as-built model", "operations and maintenance scheduling", and "building maintenance scheduling" functions were not preferred since those functions are insignificant in the stages. Additionally, "digital fabrication" and "field supplements" functions were rejected because they were incompatible with managing highly important causes. Even though some respondents identified "quality management", "energy analysis and optimisation", and "field supplements" as suitable to manage some highly important causes, they were unable to obtain more than 60% of agreement from the respondents. Finally, twenty-five (25) BIM functions were selected to manage the highly important causes, with the confirmation of more than 60% of the respondents. Results from this stage were summarised in Table 3.

4.3 SUITABLE BIM FUNCTIONS THAT CAN BE USED TO MANAGE THE HIGHLY IMPORTANT CAUSES OF COST OVERRUN IN D&B PROJECTS

In round 2, phase 2, each respondent was asked to select five (5) most suitable BIM functions, considering their significance towards managing the particular highly important cause of cost overrun. Out of the matched BIM function to each cause, functions with more than a 60% agreement rate from the respondents were selected as suitable BIM functions to manage the particular cause of cost overrun. Findings are summarised in Table 3.

Table 3: Most suitable BIM functions to manage highly important causes for cost overruns in D&B projects

No.	Highly important cause	BIM functions
01	Continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at the tendering stage	Change and revision management Cost estimation (5D) and management Interoperability and exchange of information Design documentation Digitalised quantity take-off Cloud computing
02	Errors or omissions revealed during construction	Digitalised quantity take-off Clash detection Design and constructability reviews

No.	Highly important cause	BIM functions
		Structural analysis
		Modelling existing conditions
		Interoperability and exchange of information
		Modelling design and engineering analysis
03	Inefficient planning and scheduling by the contractor	Planning and scheduling (4D)
		Safety planning and review
		Trade coordination
		Site utilisation planning
		Clash detection
		Field and management tracking
04	Inadequate constructability of the design	Constructability reviews and building simulation
		Modelling existing conditions
		Site condition analysis
		Clash detection
05	Inappropriate construction methods followed by contractors	Construction system design
		Site condition analysis
		In-field construction layout preparation
06	Lack of clarity in the employer's brief	Modelling existing conditions
		Constructability reviews and building simulation
		Interoperability and exchange of information
		Design coordination
		Design documentation
		Cloud computing
07	Issues relating to D&B are not properly addressed in the Conditions of Contract	Design authoring
		Design documentation
		Interoperability and exchange of information
		Safety planning and review
08	Improper geotechnical investigations	Site condition analysis
		Disaster planning
		Constructability reviews and building simulation
09	Unforeseen weather and site conditions experienced D&B contractor could not have predicted	Site condition analysis
		Disaster planning
		Sustainability evaluation
		Safety planning and review
		Occupational safety analysis (8D)
		Modelling design and engineering analysis
10	Poor communication between design and construction teams	Interoperability and exchange of information
		Cloud computing
		Clash detection
		Change and revision management
		Design authoring
		Digitalised quantity take-off
		Design coordination

According to Table 3, BIM functions commonly selected for managing the highest number of causes are "interoperability and exchange of information" and "clash detection". Those two functions were recognised to address five and four highly important causes, respectively. Some other BIM functions such as "digitalised quantity take off", "cloud computing", "design documentation", "safety planning and review",

"constructability reviews and building simulation", and "site condition analysis" were chosen to manage three different highly important causes for cost overruns for each.

4.4 DISCUSSION

Adamtey (2021) stressed that D&B contractors should pay immediate attention to addressing the price uncertainty of the projects. Most previous studies on cost overrun are based on traditional procurement methods, and limited studies focused on D&B projects (Potty et al., 2011; Saaidin et al., 2017;). Therefore, validating the applicability of common causes for cost overrun for D&B projects was required. El-Ahwal et al. (2016) declared that scope changes, design errors, inadequate planning, and delays increase the risk of cost overrun in typical projects. This study confirms that these exact causes apply to D&B projects. Ramanathan et al. (2011) also identified "continuous changes in design and drawings at tendering stage" as a critical factor for cost overrun in D&B projects. This study approved it as a highly important cause in round 2. Further, several studies describe "errors revealed during construction" (Akinradewo et al., 2019; Johnson & Babu, 2020) and "contractor's inefficient planning and scheduling" (Akinradewo et al., 2019) as important causes for cost overrun in construction projects and present study confirms it is applicable in a similar way to D&B projects. Even though there is significant potential to adopt BIM to manage cost overrun in D&B projects, literature has not addressed that area. Therefore, identifying suitable BIM functions to manage critical causes for cost overrun in D&B projects was the research gap that was intended to fulfill through this study. In that case, common functions of BIM, recognised from the comprehensive literature, were validated through the interview process, and no alterations happened. Many past researchers identified "interoperability and exchange of information" and "clash detection" are the most specific and unique functions of BIM (Abdel-Hamid & Abdelhaleem, 2023; Ganbat et al., 2020; Gholizadeh et al., 2018). Respondents also recognised their significance and highlighted that these two functions could be used to manage multiple highly important causes of cost overrun in D&B projects. Furthermore, several other BIM functions as "digitalised quantity take-off", "cloud computing", and "constructability reviews and building simulation", were previously identified by different authors (Bello et al., 2021; Brahim et al., 2018; Gholizadeh et al., 2018) are recognised by the respondents as effective in managing multiple critical causes for cost overrun in D&B projects.

5. CONCLUSIONS

The aim of this study was achieved through the literature review and two rounds of interviews. Twenty-five causes for cost overrun in D&B projects were identified, validated and categorised into three categories according to their criticality level. Ten causes were recognised as highly important causes for cost overrun in D&B projects such as "continuous changes in design and drawings ", "errors/omissions revealed during construction", "inefficient planning and scheduling by contractor", "inadequate constructability of the design" and "inappropriate construction methods followed by contractors". A significant proportion of the causes identified as contributing to cost overrun in the D&B method can be alleviated by implementing efficient construction management practices. Given this observation, it is reasonable to assert that BIM represents a promising solution to address these challenges. Thirty-five BIM functions were identified from the literature review and validated by the respondents as they are

aware of them. Identified BIM functions were matched with the highly important causes as their applicability to manage the cause successfully. In that case, "interoperability and exchange of information", "clash detection", "digitalised quantity take-off", "design documentation", "cloud computing", "constructability reviews and building simulation", "safety planning and review", "site condition analysis" were confirmed as functions that can be commonly used to manage multiple highly important causes for cost overrun in D&B projects. The study revealed that the interoperability of BIM could mitigate continuous changes in design drawings, increase the clarity of the client's brief, increase the coverage of conditions of contract to address issues in the D&B method and improve communication. Most importantly, the clash detection function is undeniably helpful in reducing errors and omissions, improving planning efficiency and the design's constructability. Overall, these findings highlight the potential of BIM to improve project outcomes in D&B construction, making it a valuable tool for the industry.

This research aims to investigate the use of BIM to manage cost overrun issues in D&B projects. Thus, the study findings can be used as a reference when conducting further studies on managing pricing risk in D&B projects with BIM and other digitalisation technologies. The findings will foster and encourage the successful adoption of digitalisation technologies for managing unique and critical challenges in the construction industry. Since the majority of the respondents of this research have their experience related to the Sri Lankan context, the study cannot be generalised in the global context,

Despite their essential advantages over traditional procurement method, the risk of cost overrun is one of the most common, critical and unsolved issues in D&B projects faced by the contractor. Therefore, identification of highly important causes for cost overrun and suggesting the most suitable BIM functions, industry professionals will be able to prioritise the risks and implement the most appropriate and convenient BIM function to address them. The full potential of BIM has not been revealed yet. Thus, this study can be used as a benchmark for future studies by revealing another parameter of the applicability of BIM in reducing the pricing risk of D&B projects. Furthermore, future studies can be conducted to identify barriers to implementing identified BIM functions and suggest suitable strategies to overcome those barriers.

6. REFERENCES

AbdelHamid, M., & Abdelhaleem, H. M. (2023). Project cost control using five dimensions building information modelling. *International Journal of Construction Management*, *23*(3), 405–409. https://doi.org/10.1080/15623599.2021.1880313

Adamtey, S. (2021). Cost and time performance analysis of progressive design-build projects. *Journal of Engineering, Design and Technology*, 19(3), 686–697. https://doi.org/10.1108/JEDT-05-2020-0164

Adamu, I, Sidik, M. A., & Ernest, O.T. (2017). Adopting design and build (D&B) as an alternative construction procurement system to the traditional method in Ghana. *International Journal of Construction Engineering and Management*, 6(4), 148-159. https://doi.org/10.5923/j.ijcem.20170604.03

Adnan, H., Bachik, F., Supardi, A., & Marhani, M. A. (2012). Success factors of design and build projects in public universities. *Procedia - Social and Behavioral Sciences*, 35, 170–179. https://doi.org/10.1016/j.sbspro.2012.02.076

Ahmed, S., & El-Sayegh, S. (2020). Critical review of the evolution of project delivery methods in the construction industry. *Buildings*, 11(1), https://doi.org/10.3390/buildings11010011

Akinradewo, O., Aigbavboa, C., & Akinradewo, O. (2019). Revisiting causative factors of project cost overrun in building construction projects in Nigeria. *IOP conference series: Materials science and engineering*, *640*(1), 012002. https://doi.org/10.1088/1757-899X/640/1/012002

Ayuningtyas, D., & Rarasati, A. D. (2020). Work acceleration srategy development on design-build project to improve risk based quality performance. *Global Journal of Science & Engineering*, *2*, 10-15. https://doi.org/10.37516/global.j.sci.eng.2020.007

Azhar, S., Khalfan, M., & Maqsood, T. (2015). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15–28. https://doi.org/10.5130/AJCEB.v12i4.3032

Badran, D., AlZubaidi, R., & Venkatachalam, S. (2020). BIM based risk management for design bid build (DBB) design process in the United Arab Emirates: a conceptual framework. *International Journal of System Assurance Engineering and Management*, *11*(6), 1339–1361.

Bello, S., Oyedele, L., Akinade, O., Bilal, M., Delgado, J. M., Akanbi, L.,Owolabi, H. (2021). Cloud computing in construction industry: Use cases, benefits and challenges. *Automation in Construction*, 122. https://doi.org/10.1016/j.autcon.2020.103441

Borg, L. (2015). *Procurement contracts, innovation and productivity in the construction sector: Five studies.* Stockholm: KTH Royal Institute of Technology.

Brahim, J., Latiffi, A. A., & Fathi, M. S. (2018). Application of building information modelling (BIM) in design and build (D&B) projects in Malaysia. *Malaysian Construction Research Journal*, *25*(2), 29-41.

Braglia, M., Dallasega, P., & Marrazzini, L. (2022). Overall Construction Productivity: a new lean metric to identify construction losses and analyse their causes in Engineer-to-Order construction supply chains. *Production Planning & Control*, *33*(9), 925–942. https://doi.org/10.1080/09537287.2020.1837931

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8), 652–661. https://doi.org/10.1177/1744987120927206

Cunningham, T. (2015). *Cost control during the pre-contract stage of a building project: An introduction.* Dublin: Report prepared for Dublin Institute of Technology. https://doi.org/10.21427/83w4-r689

Disney, O., Johansson, M., Leto, A. D., Roupé, M., Sundquist, V., & Gustafsson, M. (2021). Total BIM project: The future of a digital construction process. *Industry 4.0 applications for full lifecycle integration of buildings*, 21-30, Middleborough: Teesside University, United Kingdom.

Döringer, S. (2021). The problem-centred expert interview. Combining qualitative interviewing approaches for investigating implicit expert knowledge. *International Journal of Social Research Methodology*, *24*(3), 265-278. https://doi.org/10.1080/13645579.2020.1766777

El-Ahwal, M., El- Attar, S., & Abdel-Hafez, W. (2016). Factors leading to cost overrun occurrence in construction projects. *Port-Said Engineering Research Journal*, *20*(1), 71–77. https://doi.org/10.21608/pserj.2016.33641

Ganbat, T., Chong, H.Y., & Liao, P.C. (2020). Mapping BIM Uses for Risk Mitigation in International Construction Projects. *Advances in Civil Engineering*, 2020, 5143879. https://doi.org/10.1155/2020/514387

Gad, G., Davis, B., Shrestha, P., & Fathi, M. (2020). Legal and contractual issues in lump-sum design-build implementation on large-scale airport projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *12*(1), 05019011. https://doi.org/10.1061/(asce)la.1943-4170.0000364

Gilkinson, N., Raju, P., Kiviniemi, A., & Chapman, C. (2015). Building information modelling: The tide is turning. *Proceedings of the Institution of Civil Engineers: Structures and Buildings*, *168*(2), 81–93. https://doi.org/10.1680/stbu.12.00045

Gholizadeh, P., Esmaeili, B., & Goodrum, P. (2018). Diffusion of Building Information Modeling Functions in the Construction Industry. *Journal of Management in Engineering*, *34*(2), 04017060 https://doi.org/10.1061/(asce)me.1943-5479.0000589

Gupta, B. N., & Gupta, N. (2022). *Research methodology*. SBPD Publications

Haupt, T. C., Akinlolu, M., & Raliile, M. T. (2019). Applications of digital technologies for health and safety management in construction. In Y.G. Sandanayake, S. Gunatilake & A. Waidyasekara (Eds.), *Towards a smart, sustainable and resilient built environment*: *Proceedings of the 8th world construction symposium*, (pp. 88-97). https://doi.org/10.31705/wcs.2019.9

Jimenez, M. C., Alarcón, L. F., Torres-Machi, C., Chamorro, A., & Molenaar, K. (2020). Improving cost performance in design-bid-build road projects by mapping the reasons for cost overruns into the project phases. *Revista de La Construccion*, *19*(2), 334-345. https://doi.org/10.7764/RDLC.19.2.334

Johnson, R. M., & Babu, R. I. I. (2020). Time and cost overruns in the UAE construction industry: a critical analysis. *International Journal of Construction Management*, *20*(5), 402–411. https://doi.org/10.1080/15623599.2018.1484864

Medelyan, A. (2020). *Coding Qualitative Data: How To Code Qualitative Research (2021) Thematic*. https://getthematic.com/insights/coding-qualitative-data/

Muhammad, M. T., Nuzul, A. H., Hizami, A., Alias, A., Taha Al-Jumaa, A., & Bala Muhammad, I. (2019). The impact of BIM application on construction delays and cost overrun in developing countries. *IOP conference series: Earth and environmental science*, *357*(1), 25-27. https://doi.org/10.1088/1755-1315/357/1/012027

Ogunsanmi, O. E., Salako, O. A., & Ajayi, O. M. (2011). Risk classification model for design and build projects. *Journal of Engineering, Project, and Production Management*, *1*(1), 46–60. https://doi.org/10.32738/jeppm.201107.0006

Olanrewaju, O., Kineber, A., Chileshe, N., & Edwards, D. (2022). Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. *Building and Environment*, *207*(Part B), 108556. https://doi.org/10.1016/j.buildenv.2021.108556

Oztas, A., & Okmen, O. (2004). Risk analysis in fxed-price design–build construction projects. *Building and Environment*, *39*(2), 229-237. https://doi.org/10.1016/j.buildenv.2003.08.018

Pham, D. H., Ly, D. H., Tran, N. K., Ahn, Y. H., & Jang, H. (2021). Developing a risk management process for general contractors in the bidding stage for design–build projects in vietnam. *Buildings* 11(11), 542. https://doi.org/10.3390/buildings11110542

Potty, N. S., Irdus, A. B., & Ramanathan, C. T. (2011, September 19-20). *Case study and survey on time and cost overrun of multiple D&B projects*. 2011 National Postgraduate Conference - Energy and Sustainability: Exploring the Innovative Minds, Perak. Malaysia. https://doi.org/10.1109/NatPC.2011.6136364

Rahmani, F., Maqsood, T., & Khalfan, M. (2017). An overview of construction procurement methods in Australia. *Engineering, Construction and Architectural Management*, *24*(4), 593–609. https://doi.org/10.1108/ECAM-03-2016-0058/FULL/XML

Ramanathan, C. T., Sambu Potty, N., & Bin Idrus, A. (2011). Risk factors influencing time and cost overrun in multiple D&B projects in Malaysia: A case study. *IEEE international conference on industrial engineering and engineering management*, *978*, (pp. 854–859). https://doi.org/10.1109/IEEM.2011.6118037

Rostiyanti, S., Bintang Koesalamwardi, A., & Winata, C. (2019). Identification of design-build project risk factors: contractor's perspective. *MATEC web of conferences*, *276*, 02017. https://doi.org/10.1051/matecconf/201927602017

Ruvinda, L. M., & Bamunuachchige, H. M. (2020). *A Study on design and build procurement methods benefits' to clients in Sri Lankan building construction industry*. Institute of Quantity Surveyors Sri Lanka

Saunders, M., Lewis, P., Thornhill, A., & Bristow, A. (2019). Chapter 4: Understanding research philosophy and approaches to theory development. *Research Methods For Business Students*

Saaidin, S., Endut, I. R., Abu Samah, S. A., Mohd Rizduan, A. R., & Abd Razak, N. N. (2017). Risk factors influencing contractor's cost estimating in design and build project in Malaysia. *Journal of Engineering and Applied Sciences*, *12*(Specialissue3). Retrieved from https://medwelljournals.com/abstract/?doi=jeasci.2017.6462.6467

Siddiqui, F., Akhund, M. A., Ali, T. H., S. H., Khoso, A. R., & Imad, H. U. (2019). Barriers in adoption of building information modeling in Pakistan's construction industry. *Indian Journal of Science and Technology*, *12*(25), 1-7. https://doi.org/10.17485/ijst/2019/v12i25/142325

Yusoff, S. N. S., Brahim, J., & Yusoff, Z. M. (2022). Building Information Modelling (Bim) as an effective communication channel among Malaysian construction. *Journal of Building Performance*, *13*(1), 17–25.