LEVERAGING APPLICATIONS OF 5D BIM TECHNOLOGY FOR BUILDING CONSTRUCTION: ENHANCING EFFICIENCY OF COST MANAGEMENT PRACTICES

LIYANAGE G.H.M.D.[1]* & KULATUNGA U.[2]
[1,2] Department of Building Economics, University of Moratuwa, Colombo, Sri Lanka
[1]*liyanageghmd.19@uom.lk* , [2]*ukulatunga@uom.lk*

Abstract: Construction cost estimation is essential to the successful management of building projects since it forms the basis for planning, budgeting, and resource distribution. Accurate and efficient cost estimation is crucial for improved project outcomes, and on-time project completion. However, traditional cost estimation methods have several issues, which are prevalent worldwide and particularly felt in Sri Lanka. The development of 5D Building Information Modeling (BIM) provides a revolutionary answer to these problems. Therefore, the aim of the paper is to investigate the application of 5D Building information modeling to enhance the efficiency of construction cost estimation. To accomplish the research aim, the qualitative research approach was undertaken. Data collection was carried out through interviews. The primary data analysis was conducted by using manual content analysis. A comprehensive literature review was conducted to determine the problems that traditional cost estimation methods face globally. In addition, the literature analysis examined 5D BIM features and how they improve cost estimation, demonstrating how this innovative method may overcome the drawbacks of traditional methods. The findings revealed the traditional cost estimation issues. The major identified issues are cost overruns, time consumption, inaccuracies, financial risks, lack of coordination, and manual quantity take-off. The results demonstrated that there are key features of 5D BIM, such as improved collaboration, clash detection, visualisation and 3D modelling, waste reduction and risk management, that can be used to mitigate traditional cost estimation issues. Therefore, using its features, the 5D BIM concept can enhance the construction cost estimation.

Keywords: *5D Building Information Modeling (BIM), Cost estimation, Traditional, Efficiency*

1. Introduction

Construction industry is a unique, dynamic, and complex sector that provides a significant impact on the economic development of a country, but it faces many challenges such as cost overruns, delays, and inefficiencies (Johnson & Babu, 2020; Othman, 2013; Prasad et al., 2019; Sambasivan & Soon, 2006). Habibi et al. (2018) stated that failure to complete construction projects on time results in delays, requiring more overhead, and a project's cost deviates from its initial predicted cost. Additionally, cost overruns occur if the project fails to be completed on schedule (Habibi et al., 2018). Cost estimation is an analytical way of determining costs, and it indicates better outcomes in construction projects when it is accurate and efficient (Doloi, 2013). Therefore, quantity take-off and cost estimating have been identified as time-consuming procedures in construction sector (Bettemir, 2018; Kulasekara et al., 2013; Wu et al., 2014). Further, considering the increased competition within the construction industry, the effectiveness of traditional estimating techniques has been doubted (Babatunde et al., 2019). Traditional cost estimation methods mostly rely on 2D drawings to prepare cost estimates. Traditional cost estimation methods involve manually interpreting and determining quantities and calculating costs (Wu et al., 2014). The initial phase in the traditional project design process involves understanding and translating the architectural plans; drafters typically begin the drawing process to depict the building and initiate the construction documentation. This results in the generation of redundant drawings with duplicated information (Hunt, 2013).

In recent years, Building Information Modeling (BIM) has become an interactive method as a solution for the cost related problems, and it is a digital representation of both physical and functional characteristics of a building by providing design, visualisation, collaboration, scheduling, and cost estimation (Dash, 2021). BIM technology allows for quick and precise quantity information counting, analysis, and printing of the bill of quantities through the printing interface (Liu & Cao, 2021). Instead of being solely viewed as a technology, BIM is evolving into a systematic technique and process that alters how projects are delivered, designed, communicated, and managed organizationally (Porwal & Hewage, 2013).

One of the success factors for building projects is an accurate cost estimate because it is the only reliable approach to ensure the projects stay within the budget (Sayed et al., 2020). Moreover, through the BIM, QSs can increase their performance and productivity by reducing the time spent on quantity take-offs and allocating that time to more beneficial and essential tasks such as design advice, additional cost alternatives, estimates, and value engineering (Fung et al., 2014). In addition, BIM improves the standards of QS services by enabling the visualisation, simulation, and analysis of the effects of various design and construction scenarios by integrating cost information, quantities, and project schedules (Mayouf & Cox, 2019). Previous research has explored various advantages of 5D BIM, focusing on aspects like time efficiency (Katke,

*Corresponding author: Tel: +94712938009 Email Address: liyanageghmd.19@uom.lk
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2020; Tahir et al., 2018), cost management (Katke, 2020; Smith, 2016), and project planning (Hathiwala & Pitroda, 2021; Rui et al., 2021). However, there has been a lack of specific investigation into its efficiency in cost estimation. Therefore, this paper aims to comprehensively investigate cost estimation using 5D BIM, providing in-depth insights into its application and effectiveness. Accordingly, the research question of this study is "What are the ways to enhance the cost estimation efficiency of construction through 5D Building Information Modeling (BIM) technology."

Accordingly, the aim of the paper is to investigate the application of 5D Building information modeling to enhance the efficiency of construction cost estimation. The research narrowed to building construction and provide an understanding of how integrating BIM can optimize cost estimation practices. The paper is structured as followed. First, it discusses the theoretical background of the research area by collecting information from sources which include traditional cost estimation challenges, applicability of 5D BIM features and advantages of adopting 5D BIM for increasing cost estimation efficiency to overcome the identified issues. Then the paper outlines the research methodology used to gather findings, followed by an analysis and discussion of the results obtained from semi-structured interviews. Finally, the conclusion offers a summary of the overall study.

2. Literature Review

The construction industry is commonly seen as being very conservative and slow to acquire new ideas (Best & Valence, 2002; Gambatese & Hallowell, 2011; Paljak, 2019). In response to the rapid changes in design, the construction industry needs to develop systematic techniques for overseeing and managing each stage of the construction process. (Ali et al., 2020; Michael, 2001). The process of cost estimation is one of the most significant aspects of construction management (Ibrahim & Elshwadfy, 2021). In traditional cost estimation, CAD drawings would be scanned and then interpreted manually to determine the quantities that contribute to the calculation of construction cost (Monteiro & Martins, 2013; Moses et al., 2020). Due to their inefficiency, these estimating procedures consume a significant amount of time (Mayouf & Cox, 2019). Thus, 5D BIM can be introduced to address traditional cost estimation challenges.

2.1. WHAT IS BIM?

BIM is a process that uses digital information to create and manage a building's design, construction, and operation. An example of this concept is ordering a book online compared to ordering one by mail (Ikerd, 2008). BIM entails creating and utilising intelligent 3D models that include graphical and non-graphical project information, and those models can illustrate designs, simulate building processes, assess performance, and coordinate various aspects of the project (Jones, 2014).

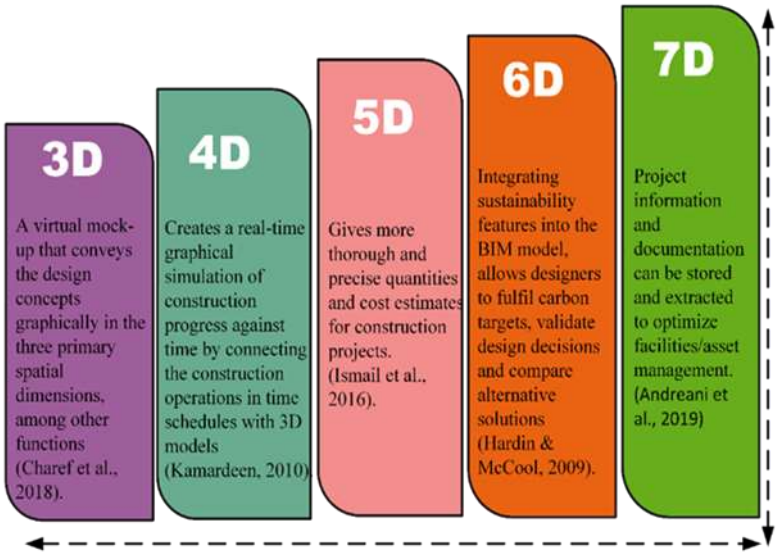

Figure 1, BIM Categorisation

2.2. ADVANTAGES OF 5D BIM FOR CONSTRUCTION

Improved Collaboration and Communication

A 5D BIM model can integrate or connect with essential cost data, allowing for the automatic generation and adjustment of bills of materials, area estimates, material costs, and other relevant estimation details when design or design-related information changes (Ashcraft, 2008). BIM transforms the conventional paper-based methods used in construction projects by transferring them into a virtual setting, enabling heightened efficiency, communication, and collaboration, surpassing the capabilities of traditional construction procedures (Lee, 2008). Furthermore, Hunt (2013) highlighted that BIM minimizes errors through automated verification, identifying clashes or conflicts between the structural system and ductwork and plumbing systems. Therefore, this feature reduces human errors due to the automation.

Visualisation and 3D Modeling

Bhusar & Akhare (2014), stated that the unique nature of structures during the construction phase leads to distinct characteristics, resulting in the alteration of material properties over time and variable loading conditions. The use of visualisations, simulations, and analytical procedures can aid in addressing potential challenges that may arise in the future (Bennett, 2012). 3D visualisation feature of the 5D BIM allows the proposed building to be viewed as a real structure. Therefore, everyone can easily understand and imagine the how the building would be after construction. Using Revit, an architectural model is developed, and after that, column positions are placed, which contains all the information related to the model, as shown in Figure 2 (Bhusar & Akhare, 2014).

Figure 2, 3D Visualisation of a building (Source: Bhusar & Akhare, 2014)

Clash Detection

Clash detection stands out as one of the most utilised applications of BIM within the construction sector (Eadie et al., 2013; Katke, 2020). The BIM identifies potential conflicts between different building design elements prior to the actual construction, as shown in Figure 8 (Azhar et al., 2012). 5D BIM enables effective clash detection and coordination to ensure the predictability of subcontractors' work (Bryde et al., 2013). Figures 3 illustrate how the clash detections show in a model. Considering about the overall 5D BIM, this feature is more important for construction projects since most of the constructions experience cost overruns due to reworks. This can assist in identifying clashed before the construction and design can be changed according to that before construction.

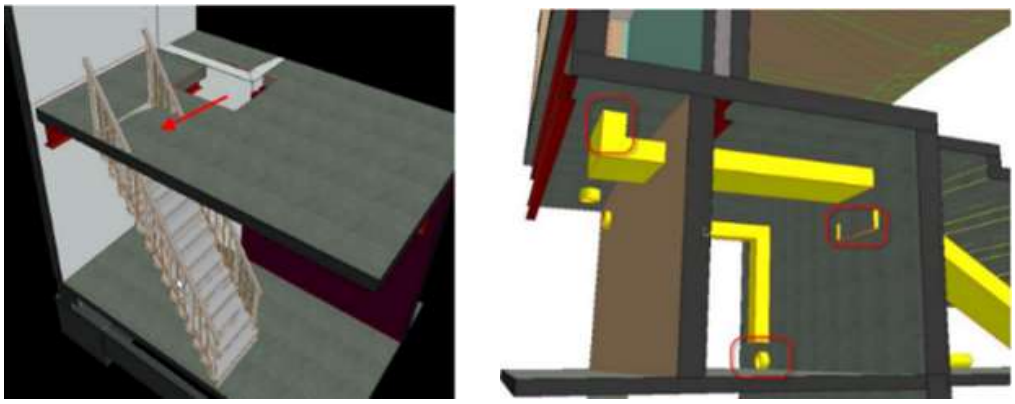

Figure 3, Clash Detections (Ghanem & Wilson, 2011)

Risk Reduction

Incorporating BIM can be a valuable component of an efficient approach for engineers to oversee the well-being and long-term performance of building components, optimize seismic retrofitting efforts, and evaluate the risk associated with constructions (Kasireddy et al., 2015; Marzouk & Hisham, 2014). 5D BIM helps to plan, control, and manage budget and cost, which leads to reduced construction risks (Hartmann et al., 2012). The use of 5D BIM in place of conventional methods leads to increased efficiency, engaging construction detail visualisation, and accurate, on-time risk assessment (Stanley & Thurnell, 2014).

Reduction of wastages

5D BIM design allows for noticing and synchronising mistakes, constructing and designing omissions and planning, using design models as the basis for fabricated components, and facilitating lean construction methods (Diaz, 2016). Identifying errors in the pre-construction phase and minimising identified errors help reduce wastage, improving cost efficiency. According to Won et al. (2016), construction waste can be decreased using 5D BIM techniques such as phase planning, quantity take-off, design validation, and site usage planning.

2.3. ENHANCING EFFICIENCY OF COST ESTIMATING FOR CONSTRUCTION THROUGH BIM

Having discussed the advantages of 5D BIM earlier, this section discusses how BIM is used to enhance the efficiency of cost estimation of building construction. BIM makes it viable to link model components with the amount of work, enhancing cost-estimating accuracy (Plebankiewicz et al., 2015). After taking off quantities from the BIM model, unit rates are computed for all items and priced automatically (O-Cheol et al., 2011). The construction process efficiency can be improved significantly with BIM-based software than with more conventional methods (Chen & Luo, 2014; Mostafa et al., 2021; Wang et al., 2022).

3. Research Methodology

Research is categorized according to several factors, such as the information sought, the study's goals, and the study's application (Hancock et al., 2007). Further, Research involves a careful examination or inquiry, particularly by exploring new facts within any field of knowledge (Kabir, 2016). Researchers typically utilize three types of research approaches: qualitative, quantitative, and mixed methodologies in various research investigations (Taherdoost, 2022; Williams, 2007).

This research assesses the cost-benefit of estimating building construction using BIM rather than traditional cost estimation techniques. Therefore, data is required regarding traditional cost estimation, issues in the cost estimation process, and benefits that can be obtained through BIM implementation. Upon evaluating the suitability of the study's aims, purposes, and fundamental characteristics, a qualitative research methodology is found to be the most appropriate method of data collection. The use of a qualitative research methodology is appropriate for this study as it aligns with the exploratory nature of the research objectives, to gain an understanding of the complexities in the construction industry, and to capture contextually relevant data essential to evaluating the effectiveness of BIM's cost estimation improvement.

Furthermore, content analysis was used in accordance with the qualitative research approach for this study. In the content analysis a code was assigned to similar opinions given by interviewees. Some codes were given based on the findings of the literature, and some codes emerged from the study. These codes helped to identify similar and different concepts for each question.

	Research Methodology	Reason
Research Approach	Qualitative Research Approach	The aim of the research was to explore ideas, opinions and perspectives in depth from the experts.
Data Collection	Semi structured interviews – Purposive Sampling	Semi structured interviews offer greater flexibility to the respondents to provide their additional opinions.
Data Analysis	Manual Content Analysis	This method was easier to the researcher to get a good idea about the similar and contradictory opinions when discussing the findings.

Expert interviews were carried out with professionals in the industry who have experience in the 5D BIM concept. Informed consent was obtained from the participants before the data collection. And also, confidentiality of the data was certified. Following Table 1 shows the details of the interviewees.

Table 1 Expert Details

Code	Experience in the Construction industry	Years of experience in BIM	Mostly familiar construction phase		Country	Designation
			Pre-Contract phase	Post-Contract phase		
R1	4	3	√		UAE	Regional education representative (SL) and Technical Manager (UAE) / A Director
R2	15	10	√	√	KSA	Associate Manager
R3	16	8	√	√	Sri Lanka	Senior QS
R4	7	9	√	√	UAE	Cost Consultant
R5	8	8	√		Australia	Lecturer in Construction Managing
R6	27	6	√	√	UAE	Senior QS
R7	3	2		√	Egypt	Scheduling Engineer
R8	7	2	√		UK	Quantity Surveyor
R9	3	2		√	USA	Assistant project executive

R10	9	9	√		UK	Research Programme Manager
R11	17	7	√	√	Sri Lanka	General Manager
R12	5	3	√		Sri Lanka	Quantity Surveyor

4. Analysis and Research Findings

This section presents a detailed analysis of the collected data and discusses the research findings.

4.1. EXISTING PROBLEMS OF TRADITIONAL COST ESTIMATION PROCESS

This provides a better understanding of the existing challenges when estimating costs using traditional cost estimation techniques. Table 1 summarises the challenges given by the interviewees.

Table 22, Challenges of traditional cost estimation identified by experts

Challenge	Literature	R1	R2	R3	R4	R5	R6	R7	R8	R9	R 10	R 11	R 12
Time Consumption	√	√	√	√	√	√	√	√	√	√	√	√	√
Less Accuracy due to human mistakes	√	√		√	√	√			√	√	√	√	√
Limited flexibility									√		√		
Inaccuracies due to reliance on historical data											√		
Lack of integration and collaboration	√	√		√	√	√	√	√					√
Issues with Traceability												√	
Difficulties in handling complex projects											√	√	
Need sound experience					√								
Difficulties in checking and changing revisions				√	√							√	
Safety issues								√	√				
Quantity can't present attractively		√											
Can missed information						√							
Not having self-satisfaction for QS		√											
Difficulty in data handling												√	

All the respondents agreed that they face significant difficulties in the traditional estimation process. However, some respondents did not agree with some issues which were identified in the literature review. All the respondents mentioned that time consumption is the major problem in traditional cost estimation techniques. Elaborating on the issue, R1 mentioned, "Use of 2D drawings spent more time understanding the drawings and imagining it as a 3D view." Besides, R1, R3, R4, R5, R8, R9, R10, R11 and R12 highlighted that accuracy would be less due to human errors. R6 added, "For example, consultants change the lighting requirements in ID drawings but contractor price according to the MEP drawings. Thus, lights appear in the ID drawings, not updated in the MEP drawings." Further, R1 mentioned that Quantity Surveyors require self-satisfaction. Because when using CAD drawings would be boring, and due to that, motivation may be decreased.

4.2. BENEFITS OF 5D BIM

Experts revealed different opinions regarding the 5D BIM benefits in relation to the cost estimation as below discussed.

4.2.1. Improved collaboration and communication for cost estimation

After identifying the existing issues of traditional cost estimation processes, other questions focused on analysing the use of 5D BIM features to enhance cost estimation accuracy. All the interviewees agreed that improved collaboration and communication in 5D BIM assist in enhancing cost estimation efficiency. All the respondents, excluding R4, believe that the BIM connects all divisions and, thus, works collaboratively. Elaborating that, R5 highlighted, "If someone changes any detail, others can see those changes" However, R11 mentioned a different opinion from other respondents. According to R11, "If

someone uses a standalone system, that will not encourage collaboration. Other than the collaboration, there is a term interoperability in 5D where you can transfer data from one platform to another."

4.2.2. Visualisation and 3D modeling for cost estimation

Most of the respondents identified this feature as beneficial in cost estimating. According to R1, R4, and R12, visualisation of a project helps to identify the project before construction. R1 mentioned, "When having 2D drawing, need to imagine it to 3D, and it can be varied from person to person. But in 5D BIM everyone has one 3D model and therefore can enhance accuracy." Furthermore, some interviewees stated that identifying cost items reduces the mistakes. However, R2 and R5 stated contradictory opinions on this question by mentioning that visualization does not directly impact cost estimation.

4.2.3. Clash detection to assist in cost estimation

This identifies how clash detection helps to increase the cost estimation efficiency. Most of the respondents other than R2, R4, and R9 stated that clash detection is important for cost savings due to reducing reworks. R1 revealed that clash detection is vital for cost savings because most construction projects identify clashes while working. R5 highlighted an example, "if a service line and column clash, the service line needs to be laid around the column due to not identifying that at the initial stage. Therefore, more quantities are required for laying the line around the column than before." According to R9, 100% clash detection is not possible at the initial stage, and therefore, it does not significantly affect the cost estimation efficiency.

4.2.4. Risk reduction in 5D BIM

According to R1 and R6, clash detection helps to minimize the risks. R1 and R6 also mentioned that accurate quantification reduces the risks of construction projects. R6 highlighted, "Quality models help to get accurate quantities, and which reduce risks." Besides, R1 stated that BIM models could forecast accurate costs because having all the details leads to accurate quantification and clash detections, which helps to estimate cost-efficiently. In addition, R7 and R8 stated that 5D BIM helps to perform risk assessment and capture the project risk areas that can cause cost overruns.

4.2.5. Waste reduction for cost estimation

Waste reduction helps save money since material costs are significantly increasing. Six interviewees mentioned that clash detection at the initial stage helps to reduce wastage by identifying errors and improving coordination. However, R2 believed that the wastage due to uncoordinated design elements or clashes could be reduced from 5D BIM since those can be identified initially. Furthermore, R3 states that "Most needed materials are calculated based on the quantification. Thus, accurate quantification can limit the purchase of imported or local materials, making the estimate accurate and economical."

4.2.6. Projects' cost estimation accuracy and cost saving with 5D BIM

All the interviewees highlighted different answers to this question, agreeing that 5D BIM helps increase cost estimation accuracy and cost savings. All the respondents except R7 and R10 stated that real-time data in 3D models increase quantification accuracy. According to R2, all the project details are provided in real time. Further, R2 explained, "For example, vertical elements would not be captured 100% from 2D drawings, but a 3D model gives all detailed information." R6 mentioned that BIM provides more realistic and accurate visualisation through a 3D model, reducing the project's cost. Similar to these opinions, R3, R8, R9, R11, and R12 mentioned that visualisation minimises mistaken cost items. Five respondents revealed that time-saving correlates with cost-saving since time is also a cost aspect. One respondent mentioned that the decision-making capabilities of 5D BIM increase the cost estimation accuracy. R7 stated, "The ability to communicate to the management increases accuracy; otherwise, information is delivered via reports, and some details may be missed due to negligence."

4.3. PRACTICAL APPLICABILITY OF 5D BIM TECHNOLOGY FOR ADVANCING COST ESTIMATION PROCESS

All the respondents furnished different opinions on the industry practices of 5D BIM, illustrating the benefits. R1 highlighted that the 5D BIM substantially impact the initial stage by developing the 3D model. Further, R1 added, "Client can award the project to the suitable contractor since client also has a good idea about the project." Most respondents highlighted the time management aspect of 5D BIM because all agreed that time can impact all the areas of a construction project. According to R2, the clients can reduce the time consumption of the pre-contract stage and enhance cost estimation efficiency by reducing costs. Further, R12 emphasised, "If a project can manage time, the contractor can do the activities smoothly, reducing mistakes and increasing accuracy." R3 and R12 highlighted another area in 5D BIM that can enhance the project's cost accuracy. R3 claimed that 5D BIM helps prepare subcontractor bills and IPA because it has a feature to mark the partially completed work. Further, R3 added, "Visualisation of work done helps to generate accurate bills."

R3 and R4 mentioned that the 5D BIM makes it easy to check the variation. Four respondents revealed that 5D BIM can check the cost of alternative material solutions. R11 stated that "5D BIM enable to analyse different options like scenario analysis." Further, R11 added the integrated project delivery (IPD) concept as a benefit that can be obtained from 5D BIM. According to that belief, IPD increases the quantity quality because, from that concept, it can divide the quantities zone-wise, subcontractor-wise, material-wise or under any other required classification. Therefore, the usage of 5D BIM improves the transparency of industry practices.

Two interviewees emphasised that cost control is easier with the 5D BIM. According to R7, controlling the cost is more beneficial in a construction project, which is easier with 5D BIM. R8 mentioned, "5D BIM increases the efficiency of cost allocation and control." Only R8 elaborated on another area that can impact 5D BIM. According to R8, material and labour schedules can be prepared easily with 5D BIM. Moreover, R11 specified that the 5D BIM streamline the estimation process. That means BIM cost estimation is a standardised process. Thus, everyone has to follow an identical way. Therefore, it helps to enhance the estimation accuracy and efficiency.

Discussion

As industry experts mentioned, using traditional cost estimation leads to more difficulties in a construction project. According to the findings of the literature, the time spent on quantity take-off depends on the project type, but 40 - 70% of the time is needed to generate cost estimates using the traditional method (Khamees et al., 2020). According to the data gathered from interviews, all respondents mentioned that more time is required for the traditional cost estimation process than the 5D BIM process. In the literature review, Dogan, (2005); Valentini et al. (2017); Hu & Skibniewski (2021) identified that traditional cost estimation requires more information. While some of the interviewees agreed with this statement, some disagreed, stating that more information was needed to develop accurate cost estimates for both traditional and BIM cost estimations. Considering all the factors, the researcher argues that developing the model needs more details and should be comprehensive to capture all data.

According to the literature findings, the 5D BIM model integrates or connects with essential cost data, allowing for the automatic generation and adjustment of bills of materials, area estimates, material costs, and other relevant estimation details when design or design-related information changes (Ashcraft, 2008). This assertion aligns with the perspective of industry experts, who emphasize that 5D BIM identify and manages design changes effectively. Moreover, 5D BIM is widely used in many countries as it enables tracking of measurements directly from the model.

Industry experts emphasised that 3D visualisation identifies significant features and reduces mistakes as all details are shown on the model. This perspective resonates with the findings of Bhusar & Akhare (2014), who stated that utilisation of BIM can help to identify potential issues early in the design phase by creating an accurate and detailed model. Thus, expert opinions reflect the findings of the literature review regarding the utilization of 5D BIM for project visualization. Therefore, the researcher highlights the importance of a 3D view for a construction project to enhance accuracy and efficiency.

According to the interviewees and literature review, clash detection is the most utilised application of 5D BIM. Therefore, both findings reveal the benefits of clash detection that can be taken from 5D BIM. According to the findings of the literature, Yang et al. (2013) highlighted that even highly experienced senior engineers may struggle to identify all clashes within 2D CAD drawings due to the significant complexity of these integrated designs. Therefore, most of the industry experts emphasise that clash detection streamlines coordination within construction projects and save time. Thus, the researcher argues that identifying clashes at the initial step leads to increased project success without raising disputes.

In the literature findings, Hartmann et al. (2012) stated that 5D BIM helps to plan, control, and manage budget and cost, which leads to reduced construction risks. Experts provide different ways to minimise the risks, as stated in the findings of the literature. As experts mentioned, clash detection, accurate quantification, integration among parties, and high data accuracy minimise the construction risk by managing the project's cost.

According to the literature review, Won et al. (2016) highlighted that construction waste can be decreased using 5D BIM techniques such as phase planning, quantity take-off, design validation, and site usage planning. The majority of the industry experts also mentioned that accurate quantification helps to reduce material wastage. Azhar et al. (2008) and Whatmore (2012) revealed that BIM can lead to a significant 80% decrease in the time required to create a cost estimate.

Cost estimation accuracy and ways of cost savings in construction projects from 5D BIM have been found throughout the literature. Industry experts revealed the importance of real-time data generation from 3D models in enhancing cost estimation accuracy within construction projects. This viewpoint is supported by the literature findings of Azhar et al. (2012), who describes the 3D modelling of the BIM concept as an object-oriented parametric modelling process. Moreover, Papadonikolaki et al. (2016) stated that using 5D BIM reduces the number of inquiries and RFI. Experts support this statement as visualisation minimises mistakes in cost items. Time-saving is the most beneficial aspect that can be taken from 5D BIM, which is also discussed throughout the literature and expert interview findings. The literature findings revealed that the time spent on quantity take-off depends on the project type, but 40 - 70% of the time is needed to generate cost estimates using the traditional method (Khamees et al., 2020). According to the literature, Khamees et al. (2020) defined that using a 5D BIM model can solve issues the designer faces during the design process. A study was conducted by developing a 5D BIM model and compare the cost estimation with the traditional CAD based method. The study confirmed that the 5D BIM enhances the cost estimation efficiency that traditional methods.

In the literature findings, Amor (2013) highlighted the importance of BIM's continuous information flow in optimising design procedures and preventing duplications among design elements. As the literature has shown, this guarantees cost reductions and design efficiency. The opinions of the interviewees supported this, showing that 5D BIM makes cost-control

procedures smoother. Furthermore, according to the findings of the literature, BIM makes it viable to link model components with the amount of work, enhancing cost-estimating accuracy (Plebankiewicz et al., 2015). Moreover, industry experts mentioned that the 5D BIM streamline the estimation process, thereby making a systematic way for cost estimation. To support this opinion, literature stated that construction process efficiency can be improved significantly with BIM-based software than with more traditional methods (Chen & Luo, 2014; Mostafa et al., 2021; Wang et al., 2022).

5. Conclusions and recommendations

The Practical applicability of 5D BIM features for enhancing cost estimation efficiency was investigated through this study. The aim of this research was attained through literature findings and expert interviews. The literature identified problems faced when estimating costs using traditional cost estimation techniques, and experts in different countries provided their opinions based on their experiences. The findings identified various problems, such as greater time consumption, less accuracy, lack of integration, limited flexibility, difficulties in checking revisions, and difficulties in handling complex projects. Cost estimation is a pivotal function within construction organizations, and accurate cost estimation yields substantial benefits. Problems with traditional cost-estimating procedures have highlighted the need for creative solutions that reduce these difficulties.

The identification of fundamental concepts and characteristics of 5D BIM has provided various approaches to address the traditional challenges associated with cost estimation. The results indicate that using 5D BIM considerably improves the overall management of construction operations. The literature offers a general understanding of the features of 5D BIM that are beneficial for cost assessment. Thereafter expert's opinions addressed specific benefits obtained through 5D BIM for enhancing cost estimation efficiency. Accordingly, improved collaboration and communication, 3D visualisation, risk assessment, clash detection, waste reduction and accuracy, and cost savings are the major advantages identified of 5D BIM. In addition, the expert interviews revealed benefits such as an integrated project delivery concept, easy linking facilities for different applications, and ease of checking variations and alternative scenarios. According to this study, it was identified that the adoption of 5D BIM for cost estimation could directly contribute towards enhancing the cost estimation efficiency of construction.

In summary, the research findings hold significant implications for enhancing practical usage of 5D BIM for cost estimation process in the construction industry. Therefore, industry professionals can gain benefits by introducing 5D BIM concept and encouraging to use this technology. Furthermore, the study findings can be incorporate to real time situation such as clash detection, automated quantity take-off to reduce manual errors. Future research endeavours can be directed towards to examine the integration of 5D BIM concept with advanced technologies like artificial intelligence.

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