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The Impacts of 5D Building Information Modelling towards Cost Management in the Construction Industry

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ABSTRACT

Cost management is one of the most essential tasks in engineering construction. It is a crucial factor in the success of the project. The fifth dimension (5D) of building information modeling (BIM) has a different impact on cost management in the construction industry. Whereas, stakeholders are not eager to adopt procedures that are unrelated to their business. Therefore, this study determines the link between 5D BIM practices and cost management in the China construction industry to guarantee that the most suitable practice in 5D BIM is adopted. A systematic review method was adopted to assess the 5D BIM approaches to conduct the relationship between 5D BIM practices and cost management. The research involves references to the science journal databases Emerald Insight, Science Direct, and Google Scholar to find the pertinent journal publications in the data collection phases. The findings of the research indicate that the implementation of 5D BIM is agreed as beneficial, and a thorough conceptual framework is developed from this research to demonstrate the connections between 5D BIM practices and cost management in China construction sector. Cost management is optimized in various ways for 5D BIM implementation. To accomplish effective cost management and maintain their competitiveness in the market, construction industry need to comprehend the 5D BIM relevant solution and relationships. A throughout conceptual framework that demonstrates the connections between 5D BIM and its impact on the cost managment of construction industry is established through a thorough literature review, enabling stakeholders to comprehend potential benefits in cost management. The research provides new awareness and information about the 5D BIM technologies that are available concerning the demands for cost management. It address the value-added of the construction industry output and improve the industrial competitiveness of enterprises.

1. Introduction

The construction industry contributes significantly to global environmental pollution, accounting for 36% of energy use and 39% of greenhouse gas emissions [1]. Sustainable development has been

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regarded as a solution to the industry's social, economic, and environmental problems [2,3]. According to Bolade *et al.,* [4] the critical points for achieving the demands for a sustainable built environment are sustainable services design, sustainable construction, sustainable operation, and sustainable cost management. However, time and expense overruns, as well as issues with quality, are typically caused by the construction industry's complexity and fragmentation [5]. The existence or economic justification of a project may be in jeopardy even if it performs well technically due to poor cost performance [6]. Therefore, projects executed by construction companies should consider cost management, which is a crucial factor in the company's competitiveness and in achieving sustainable development.

Building information modeling (BIM) is an inventive and viable approach to improve the Architecture, Engineering, and Construction (AEC) industry [2,7]. BIM is software that generates a proposed model for a structure that reacts to modification in the same manner as the actual construction blueprint [8]. In that regard, Thurairajah and Goucher [9] argued that using BIM is essential for trustworthy and accurate cost estimation. BIM provides an effective way to reliably generate takeoff, counts, and measurements using the updated model [10]. In particular, The fifth dimension (5D) of building information modeling (BIM) provides a comprehensive and collaborative strategy for cost management and control throughout the project lifecycle [11]. 5D BIM technology stores and edits engineering information, including cost factors, using a central database and an independent information model. Kehily and Underwood [12] evaluate 5D BIM throughout a building's life cycle, while Lu and Harrison [13] solely investigate the early stages of the construction.

Even though BIM provides several benefits for project cost management, many construction projects fail to capitalize on them. A considerable distance separates the innovators (early adopters) and the remainder of the industry [14]. In comparison, stakeholders are not eager to adopt procedures that are unrelated to their business. Failure to recognize the benefits of BIM in project cost management is a wasted opportunity and a substantial risk to project success [15]. Failure to recognize the advantages may result in more significant expenses, rework, and blunders in building projects[16]. These dangers can cause project failures and severely impact the construction industry and society [15]. To establish effective BIM implementation methods, stakeholders must first understand the root reasons for BIM implementation failures [17].

In this context, a detailed examination of 5D BIM solutions on cost management can offer researchers a detached perspective of the evolving trends and restrictions of 5D BIM attributes in the industry and the academy. LLatas *et al.*, [18] establish the benefits of their framework based on BIM Application in the initial design stages. For the goal of assisting contractors in making economically beneficial decisions, Elghaish *et al*., [19] created a precise 5D BIM-based cash flow analysis framework for building projects. However, an impartial framework for calculating complete cost management in accordance with 5D BIM solutions is still lacking. As 5D BIM solutions integrate into their cost management, such a framework can prove useful for practitioners in helping them make well-informed judgments. With a comprehensive framework, organizations can pick the most adequate practices from 5D BIM and increase their competitiveness based on their requirement. Therefore, this study determines the link between 5D BIM practices and cost management in the construction industry to guarantee that the most suitable practice in 5D BIM is adopted.

2. Literature Review

This study employs a literature review technique, as utilized by Meng *et al*., [18], to uncover the components of a compromise framework between 5D BIM practices and company competitiveness.

Based on a systematic review of existing literature, a conceptual framework will be established, and it is anticipated that the conceptual framework may help with the acceptance and implementation of 5D BIM. This article used the most prestigious index databases, Web of Science (WoS) and Scopus, to undertake a thorough retrieval procedure to find relevant journal publications. This literature review comprises three main steps (Figure 1): (i) Literature compilation; (ii) filtration of relevant literature; (iii) and Category Choice.

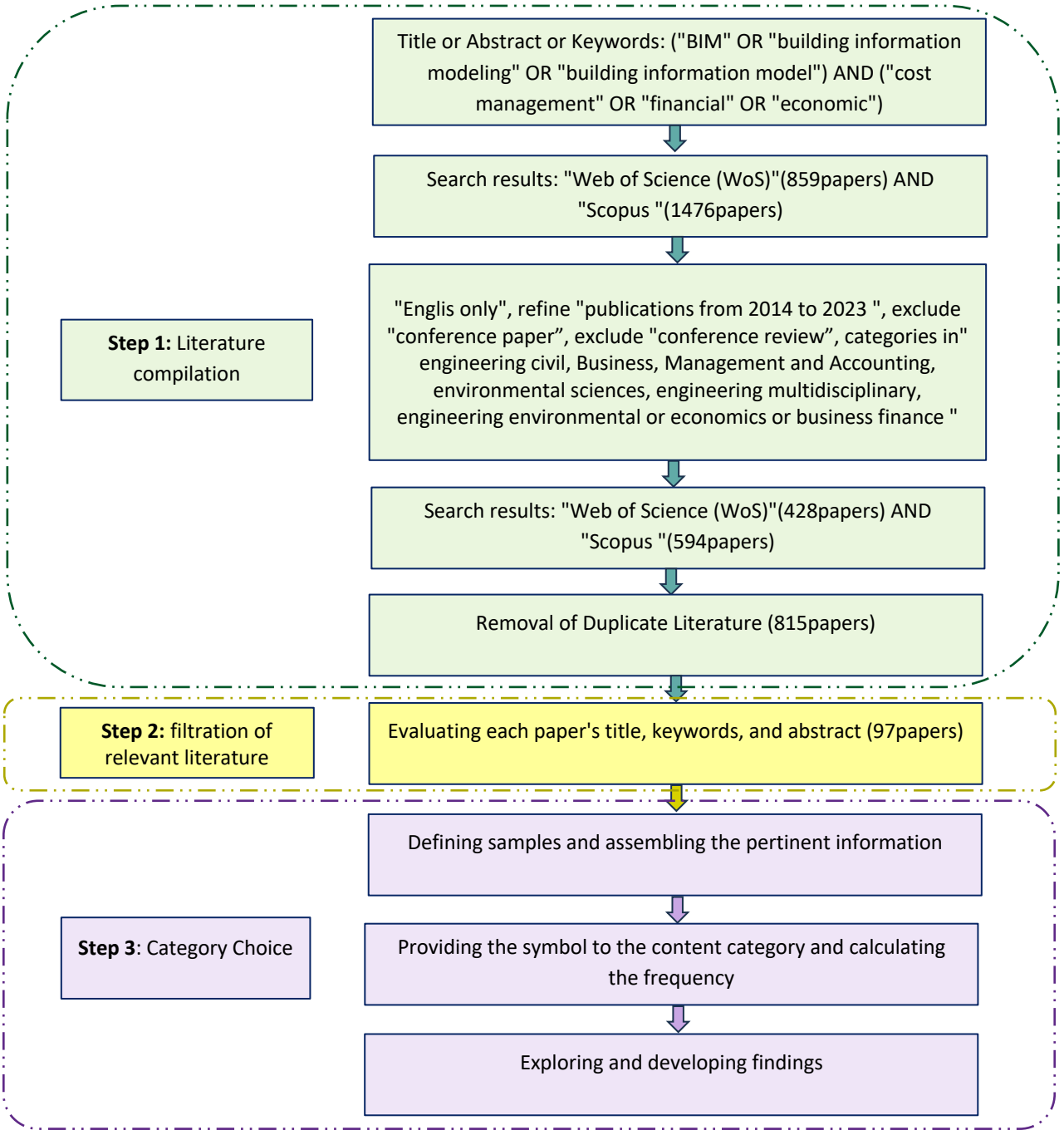

Fig. 1. The procedure of systematic literature review

2.2 Filtration of Relevant Literature
2.1 Literature compilation

This study aims to evaluate the literature from a decade ago on the effects of 5D BIM practices on cost management. To fully comprehend 5D BIM-integrated cost management, this study undertook an exhaustive retrieval procedure based on the most recognized indexed databases, Web of Science (WoS) and Scopus. The primary activity done was a thorough search. These publications include featured conference proceedings and research papers. Consequently, various parameters and conditions are set to filter out unrelated findings to increase the reliability of the acquired results and prevent overlapping publications to ensure the gathered literature articles are in the field of investigation. In addition, to reflect the most recent trends and research, only publications published in the past decade (2014–2023) will be considered. After duplicates from various search engines were removed, 815 papers were chosen.

2.2 Filtration of Relevant Literature

The titles, keywords, and abstracts of irrelevant publications were scanned for elimination. The publications that could have given pertinent information were removed from this study since it was limited to topics relating to the integration of BIM with cost. 97 publications were still available for analysis following the screening.

2.3 Category Choice

An adequate assessment of the current concrete structure may be done, given that the necessary dimensions of the 5D BIM features have been covered. An organized approach is established to do the literature review to ensure it is done effectively. The methodological procedures for performing a systematic literature review are provided below [21].

i. To determine samples and gather pertinent data for content analysis. It is crucial that 5D BIM be implemented in all nations since varied cultures and viewpoints will lead to various outcomes. Hence, in addition to being organized according to their countries, the selections were divided according to their borders and localities. Additionally, different practical aspects that affect cost management will have various impacts depending on the differences between the sectors. Consequently, to get the most accurate data, it is crucial to collect all 5D BIM's effects on cost management across various sectors. 97 papers were identified for review in this paper according to the above labels, such as country and industry.
ii. To define a code for each kind of information and to specify the frequency each code arrives. The text that has to be evaluated provides a label named a code. It has determined which study fields are more attractive to academic peers based on top citations using the abovementioned criteria. The frequency of citations in different journals is analyzed separately to find relevant literature in influential journals.
iii. To evaluate and summarize the outcomes. The chosen articles were divided according to their borders and localities. Each identified journal article is read, and the effects of the 5D BIM practice on cost management are recognized. These procedures will be examined in light of their impact to determine the elements of the conceptual framework for cost management that can be applied in the construction sector. Additionally, this study aims to determine the trend of 5D BIM practices over the past

decade. Finally, each chosen journal article is read, highlighting the cost management impacted by 5D BIM techniques.

3. Analysis and Discussion

3.1 Publication Annually

The frequency analysis is first applied in the descriptive analysis to present an overview of the statistics on the 97 chosen articles and determine the trend of BIM practices. The annual number of papers with indexed publications appears in Figure 2. The reported number of publications per year demonstrates an upward tendency in publication patterns throughout time. The graph shows the number of articles published between 2014 and 2023, and the publishing trend is upward each year, which may attest to the growing awareness of and interest in BIM among scholars.

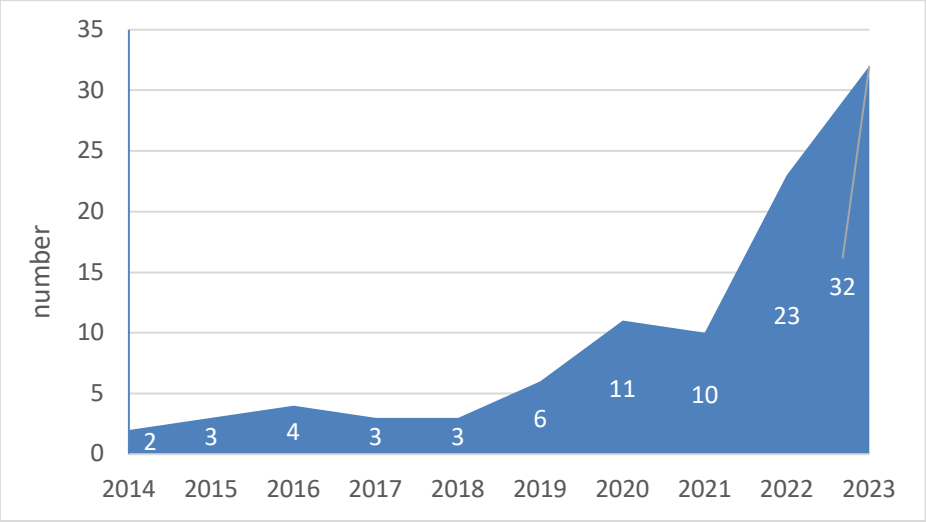

Fig. 2. The number of publications annually

3.2 Publication on Journal Papers

Table 2 also provides an overview of the types and frequency of quality journals for the recognized articles. The pattern and distribution of publications in various journals is the name of this investigation. The selected publications are broadly dispersed throughout operations, technology, and management journal articles. This demonstrates how journals on 5D BIM techniques have contributed to the corpus of current knowledge. Until July 2023, there are 57 publication papers on 5D BIM practices and cost management. Most significant journals in the field are the top five publications that publish most of the articles, including the *Automation Construction*, *International Journal of Project Management*, *Journal of Cleaner Production*, *Archives of Computational Methods in Engineering* and *Construction Innovation*.

Table 1
Journal Frequency

Journal	Article	Frequency
Automation Construction	[22–25]	244
International Journal of Project Management	[13]	110
Journal of Cleaner Production	[21,26,27]	93
Archives of Computational Methods in Engineering	[11,28]	85
Construction Innovation	[29,30]	54

Building and Environment	[31]	45
Engineering, Construction and Architectural Management	[19,31,32,33]	37
Journal of Construction Engineering and Management	[34,35]	34
International Journal of Construction Management	[36-38]	32
Journal of Building Engineering	[39-42]	31
Advances in Civil Engineering	[44]	29
Sustainability (Switzerland)	[44-48]	28
Studies in Informatics and Control	[49]	25
Civil Engineering Journal (Iran)	[50]	24
Journal of Building Engineering	[51]	23
Energies	[52]	23
Journal of Engineering, Design and Technology	[54-56]	20
Buildings	[57,59,60,61]	17
Ain Shams Engineering Journal	[62]	15
Cost Studies of Buildings: Sixth Edition	[63]	13
Sensors	[64]	10
International Journal of Civil Engineering and Technology	[65]	8
International Journal of Applied Engineering Research	[66]	7
NRM1 Cost Management Handbook	[67]	7
Open Civil Engineering Journal	[68]	4
Journal of Facilities Management	[70]	4
International Journal of Sustainable Construction Engineering & Technology	[105]	3
Smart and Sustainable Built Environment	[70]	3
Developments in the Built Environment	[72]	3
Civil Engineering and Architecture	[72]	3
Journal of Intelligent and Fuzzy Systems	[73]	3
Journal of Coastal Research	[75]	3
Journal of Civil Engineering and Management	[76]	3
Applied Sciences (Switzerland)	[77]	2
International Journal of Building Pathology and Adaptation	[79]	2
Malaysian Construction Research Journal	[79]	2
Building and Environment	[80]	2
Energy and Buildings	[81,82]	1
Advances in Engineering Software	[83]	1
Journal of Information Technology in Construction	[84,85]	1
Organization, Technology and Management in Construction	[86]	1
International Journal of Technology	[87]	1
Building Information Modeling: Applications and Practices	[88]	1
ICIC Express Letters	[89]	1
Mathematical Modelling of Engineering Problems	[90,91]	0
Energy and Buildings	[82]	0
International Journal of Sustainable Development and Planning	[92]	0
Infrastructures	[93]	0
Journal of Risk and Financial Management	[94]	0
Expert Systems with Applications	[95]	0
Iranian Journal of Science and Technology - Transactions of Civil Engineering	[96]	0
Applied Mathematics and Nonlinear Sciences	[98]	0
Frontiers in Sustainability	[98]	0
Paper Asia	[99]	0
Agro Food Industry Hi-Tech	[100]	0
Building Cost Planning for the Design Team: Third Edition	[101]	0
Journal of Computational Methods in Sciences and Engineering	[103]	0

3. 3 Publication of geographical location

Figure 3 displays the geographic location of each published article in this study. Different nations and industries will impact BIM practices and business performance differently. As a result, any article on a foreign nation should be considered. Figure 3 illustrates that China and Australia publish substantially more articles than other nations, indicating that these nations have significantly advanced BIM techniques in cost management. Malaysia and the United Kingdom are following. As a result, there is an excellent significant opportunity for BIM practices as more than 83.3% of the nations absence study on the application and practice of BIM. Considering those specific countries, like China and Brazil, may publish content in their native tongues in addition to English. Figure 3 may only depict a portion of reality as a result.

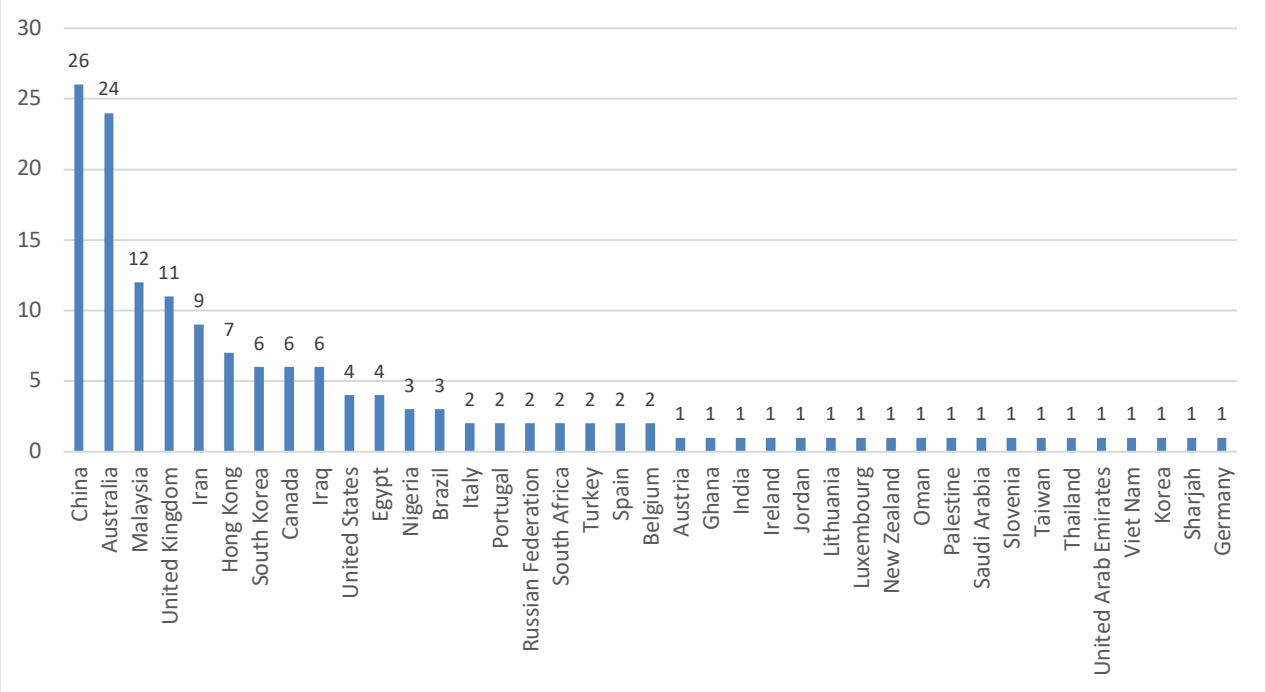

Fig. 3. Publication by country/region

3.4 Publication of Industry Type

The industry category is significant in determining the proper BIM techniques to implement, considering every sector has rules and regulations. Consequently, the assigned mentions were chosen to facilitate the categorization process. Figure 4 shows that the dominating engineering industry comprises 68% of the collected literature. The literature from the field of business, management and accounting and environmental science are followed by this with 16% and 13%, respectively. Finally, 3% is allocated to other industries. This indicates that Bim practices are more widely implemented in engineering than in other industries.

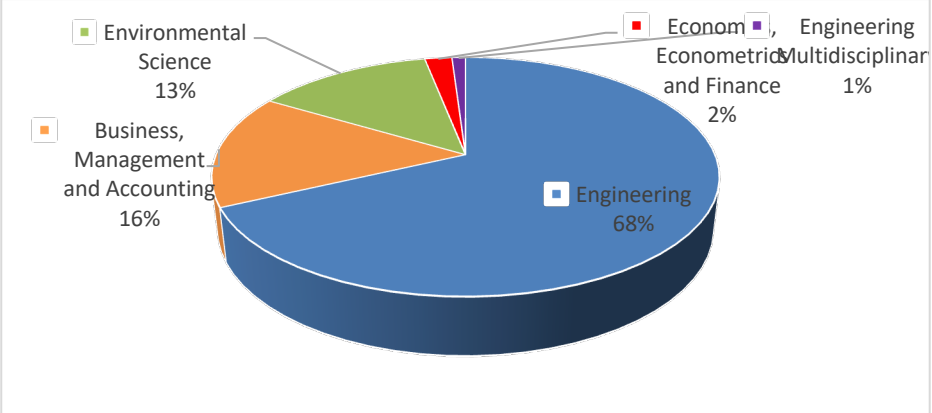

Fig. 4. Publication of BIM Practices from various industries

4.Result

BIM is a comprehensive operation that strongly emphasizes stakeholder engagement and information communication [103], which may enhance interaction project management and the final project's overall quality [104]. A digital three-dimensional model of a construction project that contains graphical and non-graphical information and is shared among participants makes up the third dimension of BIM [104]. The scheduling data included in BIM's fourth dimension (4D) enables decision-makers to comprehend better how the project will evolve while it is being built [105]. Better cost management is made possible by 5D BIM, which extends the third and fourth dimensions and can attach costing data to the digital model and the projected schedule [106].

4. 1 The Fifth Dimension (5D) of Building Information Modeling (BIM) Practices

4.1.1 Quantity takeoff

In their studies with cost consultants, Aibinu and Venkatesh [107] and Stanley *et al*., [108] have demonstrated that implementing BIM models for quantity takeoff enables the generation of materials schedules to be faster and more effectively, provided that the supplied model features the relevant information. According to Nadeem *et al*., [109], utilization of these bills of quantities combined with the 3D model of identical amounts enhanced the project's overall visualization and accuracy. According to Monteiro and Martins [110], specific values cannot be derived directly from models due to the constraints on the available tools, the structure of the model's information, or the possibility that some aspects are not represented. As a result, estimation and quantity surveyors will still be required to extrapolate quantities from the model's available data or even to enhance the models by simulating missing information in accordance with their expertise and confirm the information collected [104].

4.1.2 Procurement purchasing

Since the elements in the design equate to the components necessary to be purchased, 5D BIM technology presently offers to buy ingredients straight from the model [104]. Following that, consumers may use models created by manufacturers that contain all the specifications required for quantity takeoff, material scheduling, and cost estimation.

4.1.3 Managing change

The constant connection between the model and the costing data enables the specialists to quickly and readily evaluate the effects of modifications on overall costs [111], providing them the power to produce precise simulations of various alternatives before the element's development [112]. Additionally, the degree of development as it advances throughout the project's life cycle permits a more accurate appraisal of these modifications [113], which in specific projects significantly decreases the quantity of change orders issued [109].

4.1.4 Coordinating construction

A quick assessment of the cost expended consequently may be accomplished by isolating the model's completed components and distinguishing them by trade according to the connections between the model and the contractors' instances and quotations [111]. The deviation involving the actual costs and the budget, the components which possess the most influence on prices, and the anticipated total cost of the project may all be evaluated by comparing this data to the cash flow that was previously modeled [104].

4. 2 Cost Management

4.2.1 Cost estimating

The cost estimating components of most 5D BIM implements, combined with the quantity takeoff capabilities of the 5D BIM solutions, allow the production of cost estimates that more precisely represent the actual costs of a project [114] and overall cost reduction [16]. Eastman *et al*., [104] explain the usage of a quantity takeoff tool as employing a specific quantity takeoff tool to extract the numbers specified above. These tools often include capabilities that allow estimators to assign costs to quantities or connect them to an external database, as stated in the second technique.

4.2.2 Cost budgeting

Connecting the BIM model to the costing database allows estimators to quickly examine multiple cost and resource determinations, giving them realistic expectations of the project's conclusion [54]. 5D BIM significantly increases the client's comprehension of the project and the financial implications of his actions [35]. Integrating all of BIM technology enables better cost management early in the development process by assessing the impact of design modification, thereby improving overall project management [5]. Subcontractor prices can be introduced to the BIM model later in the project, allowing for fast assessments of budget performance and prediction [111].

4.2.3 Cost control

These are the categories of cost typically cited as developing in the initial phases of BIM implementation [52]. A modification in workflow, learning curves, and psychological resistance may originate from the development of adaptation costs [65]. According to Poirier *et al*., [115], the adoption of BIM may culminate in internal and external changes to the information flow. Organizational BIM adoption development and efficiency are severely restricted by people's aversion to altering the current workflow and stakeholder BIM knowledge [54,55]. According to statistics from

appropriate supplies, the investment decision-making stage influences the project cost by up to 80%–90%. Project decision-making is a process of selected determines the investment pproject , and the appropriateness or unreasonableness of the decision directly affects the construction success or failure of the project [5].

4.2.4 Life cycle cost analysis

The time and effort initially anticipated by the cost estimation techniques to determine the life cycle costs have been significantly reduced by the utilization of computational tools [19]. Using the fifth dimension of building information modeling, Kehily and Underwood [12] proposed a technique which allows quantity surveyors to incorporate duration costs into a model. The technique suggested utilizes a user-created mathematical framework in a pre-existing 5D BIM system, enabling an accurate and immediately upgradeable estimate of a project's lifecycle costs. Marzouk *et al.,* [25] developed a framework that facilitates the integration of a Monte Carlo simulation with an optimization model and a BIM model to evaluate the sensitivity and impact of specific material selections on the life cycle costs. This improves the accuracy of the Life Cycle Cost Analysis（LCCA）.

4.2.5 Claims

The study has been done to assess the 5D BIM practice of the available technologies to monitor and analyze claim expenses. However, Gibbs *et al*., research [46] associated the BIM t technologies with the causes causing the high frequency of construction claims and their management. The administration, pricing, and even reduction of construction claims should be achievable by BIM technologies.

4.3 Conceptual Framework

An entire collection of 97 papers from 57 publications have been chosen from the examined literature for this study's review. There are leading practices in the fifth dimension (5D) of building information modeling (BIM), which starts from the quantity takeoff, then followed by procurement purchasing, managing change, and coordinating construction. The practices in 5D BIM will enhance cost management, and the benefits are determined to be considerable after a comprehensive investigation. The described 5D BIM techniques and how to influence cost management are noted since it has been demonstrated in most of the chosen articles that 5D BIM practices will considerably enhance cost management. Following the investigation, the 5D BIM conceptual framework's components from many backgrounds have been discovered, and only suitable and practical for integration in the construction sector have been selected. Finally, as shown below, a conceptual framework for the construction business is created to serve as guidelines and a source of reference for industry practitioners.

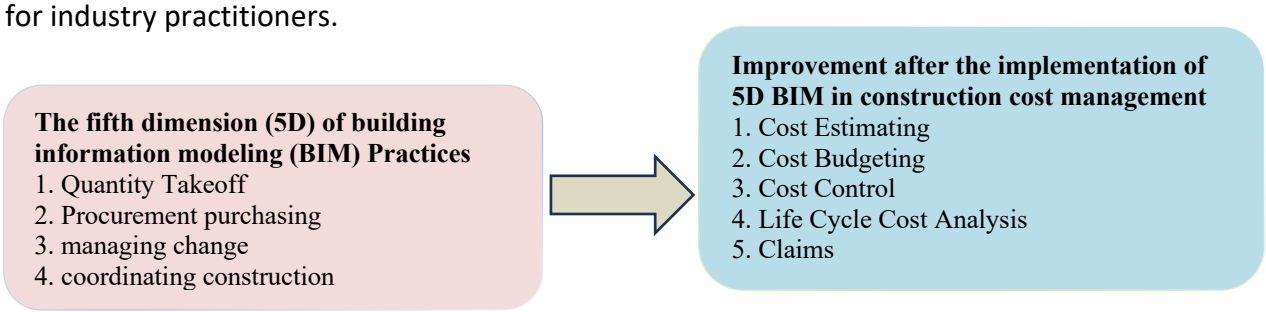

Fig. 5. Conceptual Framework

5. Conclusion

This study generated an effort to compile and present the literature that thoroughly addressed 5D BIM challenges. Through the outcomes, the research trend and prospects in 5D BIM have been emphasized. According to the descriptive analysis conducted for this research, publications dealing with 5D BIM concerns have steadily grown over the past ten years. This might increase public and private stakeholder awareness of environmental issues.

The primary purpose of the study is to present a conceptual framework through significant issues discovered during a thorough literature assessment of the field's current amount of research. The conceptual framework has been appropriately organized and aligned based on the literature research. To make the process of establishing the conceptual 5D BIM framework more accessible, the results of the literature research were further categorized. The two primary components of the generated framework are the 5D BIM practices and the effects on construction cost management. Finally, this conceptual framework benefits the parties interested in this field by offering essential information to future 5D BIM practitioners in the building sector.

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After consulting HBP office, if we would like to claim RM500 from HBP as the incentive in helping publication, we should write this sentence as the acknowledgement to the financial aid supported by HBP.

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