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Optimizing Construction Cost Control through BIM5D Digitalization: A Case Study on the Application of Glodon Software in China

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ABSTRACT

Cost managers in China have established cost control information platform for a construction phase, based on BIM5D technology, allowing for the timely and efficient integration of all cost data throughout the construction phase. However, only a small amount of study has examined BIM5D's potential for controlling building costs. Therefore, the Glodon BIM5D software is used in this study to shed some light on the software's benefit, in the construction sector who were directly involved in projects using Glodon identify the factors that influenced the development of BIM5D and propose efficient strategies to improve the software's usage in construction cost control. Key personnel BIM5D were interviewed in semi-structured interviews using a case study approach to gather data for this study. Six informants from two projects were interviewed. Interestingly, Glodon's high mobility capabilities were found a new finding in relation to the benefit of the application of the software. The most significant obstacles in using the software were cost and usability. Finally implementing effective talent development programs to improve the skills and capabilities of employees, enabling them to leverage BIM5D, was found one of the most effective strategies in this study. This study contributed significantly to introducing Glodon BIM5D software and promoting its adoption within the organization, leading to improved efficiency and effectiveness of cost control in a project environment.

1. Introduction

The expeditious growth of China's construction sector has effectively addressed the nation's demands for infrastructure development, thereby serving as an important impetus for the advancement of China's construction industry. According to statistics provided by the National Bureau of Statistics, it was observed that the yearly gross industrial output value of China's construction industry witnessed a rise from 3.8% of the nation's total production value in 1980 to 6.9% in 2015 [1]. The construction sector has encountered intense competition in the market as a result of the growth of the market economy. Simultaneously, the incorporation of China into the World Trade Organisation (WTO) in 2001 facilitated the onset of competition in the global market, and presenting substantial prospects for expansion and development, alongside the emergence of

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foreign rivals. The advent of smart buildings has ushered the construction industry into the era of big data as well.

This phenomenon has led to a need for the diversification of construction projects and the individualization of individual projects. Consequently, there has been a rise in the need for construction materials of superior quality and a wider range of construction service offerings. The advent of the information era necessitates that all conventional industries confront this reality [2]. In order to establish a competitive presence in the global market, it is imperative for Chinese construction firms to deliver superior quality, quicker, and cost-efficient products to their customers. This necessitates enhancing productivity through the utilization of information resources in the contemporary era of information, while also prioritizing the incorporation of information technology.

The advent of smart buildings has ushered the construction industry into the era of big data. Building Information Modelling (BIM) is a specific type of model used in the field of construction and can be regarded as an integral component of smart buildings. It has been four decades since the inception of Building Information Modelling (BIM) in 1975, and the industry is gradually acknowledging its significance. If to consider the emergence and quick development of Computer-Aided Design (CAD) during the 1980s as the initial revolutionary in the construction industry, it can be argued that the subsequent maturity and widespread implementation of Building Information Modelling (BIM) technology in recent years represents the second revolution in this sector [3]. Building Information Modelling (BIM) is a comprehensive representation of a building model in three-dimensional space. This model serves as the foundation for integrating time and cost information, resulting in a five-dimensional building information system that encompasses three dimensions for spatial representation, one dimension for progress tracking, and another dimension for cost estimation [4].

In contrast to BIM3D, BIM5D incorporates engineering quantity, engineering progress, and engineering cost, enabling the calculation of not just engineering quantity and progress, but also engineering cost. Additionally, the integration of the 3D model of building components with ongoing projects allows for the dynamic simulation of construction changes and facilitates real-time monitoring of progress control and cost management. In the context of the information age, BIM5D emerges as an innovative information processing tool that holds significant potential in the construction industry. By encompassing the entire construction process, it has the capacity to optimize resource allocation for construction companies, thereby facilitating cost reduction, profit enhancement, and efficient management. Consequently, BIM5D contributes significantly to the advancement and evolution of engineering cost management technology [5].

BIM5D is a technology that has emerged as a result of the ongoing advancements in Building Information Modelling (BIM). It involves the integration of BIM technology with construction progress and construction cost, enabling dynamic adjustments and cost savings. Consequently, it serves to increase the fundamental capabilities of organizations. In recent years, the Chinese government has actively advocated for the adoption and integration of BIM5D technology within traditional construction projects, with the aim of facilitating dynamic monitoring capabilities. Numerous software businesses are currently engaged in the active development of associated products. One notable option in this regard is Glodon BIM5D, which offers a practical solution for construction firms seeking to implement BIM5D to their construction practices. The subject matter encompasses a range of elements pertaining to the management of quality, cost, schedule, and safety within the construction process. The base software is a comprehensive tool that offers capabilities for model building and analysis. It has gained increasing popularity among construction organizations as they embrace digital advancements in the field of construction.

However, currently there are construction organizations that do not utilize BIM5D technology for cost control during the construction process. A significant number of managers exhibit shortcomings in their ability to effectively oversee projects utilizing Building Information Modelling (BIM) at the 5D level, particularly in the context of actual construction projects [6]. A comprehensive examination of study findings on BIM5D reveals that a substantial body of domestic researchers has undertaken investigations on the subject matter. Nevertheless, the inadequate implementation of BIM5D technology in China has resulted in a lack of emphasis on engineering cost, which is a crucial part of engineering construction management [4].

Regarding software, the initial expenditure associated with software acquisition can be major hence discouraging many organizations from allocating significant resources towards extensive training. In turn, this lack of investment directly contributes to a notable decrease in software implementation. The technical support capabilities of providers of Building Information Modelling (BIM) technologies also exhibit variability. This phenomenon gives rise to apprehensions that organizations would perceive the initial expenses associated with adopting novel technologies as excessively burdensome. In contrast, the conventional method, despite its inefficiency in terms of human and material resources, remains firmly entrenched and operational in China, hence impeding the progress of BIM5D in a subtle manner.

Second, universities are receiving a sufficient amount of attention, but organizations have not yet caught up in the area of talent development [7]. In addition, BIM5D technology is utilized by relatively few initiatives in business settings. Even for engineers who have mastered BIM5D, there are fewer opportunities to use the software, and schools invest a significant amount of money to teach it. They have invested a substantial amount of money in researching this technology, hired experts in this field to teach at the school, and created a specialized course for it. Students' practical skills and learning outcomes are unsatisfactory, however, because they have not established effective partnerships with companies. The comprehension of Building Information Modelling (BIM) technology exhibits variation among countries and industries, resulting in the development of diverse software applications. According to [8] developers tend to prioritize the performance of individual software components, often overlooking the interaction and compatibility across numerous performances. Consequently, this approach may lead to comparatively subpar compatibility performance.

After a number of fact-finding sessions, it was determined that the number of studies conducted by local academics on actual BIM projects has been insufficient to identify the significance and benefits of BIM5D in construction cost control, in addition to those identified from literature reviews and other BIM resources. The majority of BIM research has focused on its benefits, risks, obstacles, and limitations. To increase the number of BIM users in China, with a particular emphasis on BIM5D, it is necessary to conduct research on extant BIM projects that have utilised BIM5D throughout the entire project. This BIM5D-based initiative could serve as a template for future BIM5D implementation. Consequently, this study examines real BIM projects that have encountered barriers and evaluates how these barriers can be surmounted so that BIM5D can be used in the future, as well as their benefits and significance.

The objectives of the research are as follows:

i. To investigate the significance and benefits of BIM5D in China's construction industry.
ii. To Identify the factors influencing the growth of BIM5D in China.
iii. To propose effective strategies to increase the use of BIM5D in the construction industry in China.

This paper's research focuses on construction costs and does not employ a comprehensive research perspective. It contributes a new research perspective to the field by highlighting the unique benefits of BIM5D technology using a specific perspective. The inclusion of BIM5D technology in this study has expanded the research boundaries of construction cost management theory to a certain extent.

2. Literature Review

2.1 Review of the Development of BIM5D in Other Countries

The implementation of construction cost control globally commenced very early, with the earliest initiatives emerging adhering to the First Industrial Revolution. These countries began to prioritize and emphasize the importance of cost management in construction projects. The field of BIM has shown significant advancement in international research, as evidenced by the extensive literature available for reading and study. Numerous researchers have performed comprehensive investigations into various aspects of BIM. A comprehensive examination of global trends in Building Information Modelling (BIM) development reveals that the scope of BIM research is not confined to a singular direction. Instead, there is a growing emphasis on interdisciplinary research, with particular attention given to key areas such as BIM application functionalities, implementation strategies, information data flow, and issues related to project management.

As evidenced by the data presented in Table 1, it is apparent that by the beginning of the 21st century, every country had established its own distinct national costing planning. In summary, it can be observed that the Chinese academic circle is currently engaged in ongoing discussions pertaining to cost management during the construction phase. The aforementioned studies encompass several areas of BIM5D in construction management, including cost control, schedule management, quality control, and application analysis.

Table 1
History of the development of BIM representative countries

Country	History of Development	Reference
The United States of America	• In 2006 federal agency develop a 15-year development plan for BIM technology, and in 2008 a series of application standards were developed.	[9]
	• BIM technology was combined with camera technology to enable simulated construction.	[9]
	• The concept of BIM4D was first introduced by combining BIM technology and construction progress. A 4D production modelling system and a PM4D system have been successfully implemented to enable 4D visualisation and simulation as well as construction collision identification.	[6]
	• BIM 4D technology is used to represent the time dimension in order to rationalise construction sequencing and construction resources.	[6]
	• The advantages of using this BIM5D technique for visualising and managing project schedules, identifying project risks and improving construction efficiency are highlighted and the barriers to its application are described.	[10]
	• A BIM5D system was proposed that integrated time and cost management, optimised costs and detected collisions between components, resulting in a major breakthrough in dynamic cost management for construction projects.	[11]
Singapore	• The Singapore government has mandated that approval drawings in the areas of architecture, structure and M&E must be electronic, encouraging construction companies to apply BIM technology in the workflow of construction projects.	[11]
South Korea	• South Korea gave birth to a complete set of BIM technology standards from the state, industry sectors and corporate projects, and in January 2010, it released guidelines for the application of BIM in the construction sector.	[11]

The United Kingdom	• The UK was the first country to put forward the concept of cost control, as early as 1868, the UK prepared a trade association of professional surveyors, after subsequent development, is the famous Royal Institute of Chartered Surveyors, referred to as RICS, RICS in 2019 released a standard calculation guide for construction projects, as of now this has developed to the seventh edition.	[10]
China	• The BIM Institute was established in Hong Kong in 2009 and has been widely used. In 2016, Guangxi Province, Tianjin City, Yunnan Province, and many other provinces have promulgated and out on further policies to further promote the application of BIM.	[12]
	• Analysed and extracted the management data of the change plan by studying the simulation of different change plans of the office building case by BIM5D construction management software. Combined with the case simulation process to discuss the advantages and disadvantages of BIM5D technology, to provide reference for promoting the development and application of BIM5D technology in the domestic construction industry.	[4]

2.2 Review of the Development of BIM5D in China

According to Ding Chuanqi [10], China's BIM technology significantly lags behind that of foreign countries. Consequently, the initial adoption of BIM technology in China was facilitated through its importation from overseas sources. Notably, Beijing, Shanghai, and the Pearl River Delta, which are economically advanced regions, have emerged as prominent areas where BIM technology has been successfully implemented in numerous application projects. The utilization of this technology is primarily observed in pre-construction collision checking, construction simulation, and volume comparison. However, its application during the design stage requires further enhancement. Conversely, it finds more extensive application during the construction stage, yet it has not yet reached the level of whole life cycle project management [7].

Luo [13],conducted a study which revealed that Chinese construction companies commonly employ a management strategy that prioritizes target cost as the primary control objective during this particular phase. However, in the current implementation, the project's people fail to allocate sufficient attention to cost management, and there is a lack of clarity in the distribution of functions among different units. Consequently, the desired outcome of cost control efforts is seldom attained, resulting in the target cost being frequently surpassed. Hence, in order to attain accurate management and regulation of construction expenditures, it is imperative to enhance oversight over predetermined cost objectives and construction progress. Additionally, it is crucial to establish a well-defined functional accountability framework, along with corresponding protocols and assessment mechanisms, to accomplish the desired management outcomes and streamline the construction process. In summary, overall, the Chinese theoretical circle is currently engaged in ongoing discussions over cost management during the construction phase. The aforementioned studies encompass several areas of BIM5D in construction management, including cost control, schedule management, quality control, and application analysis. The findings of this research serve as a fundamental framework for the effective implementation of BIM5D and establish the groundwork for the advancement of BIM5D.

2.3 Importance and Benefits of BIM5D

BIM5D is currently the subject of extensive research and implementation by numerous companies and is anticipated to emerge as a prominent trend in the foreseeable future, with its adoption expected to expand significantly. Upon comprehending the concept of BIM5D, it is vital for one to understand its significance and advantages. Below are some of the importance and significance of BIM which were commonly cited by researchers.

2.3.1 Easier data management

According to the [14] BIM5D platform, managers have the capability to input pertinent change, and visa information, and make real-time modifications to the BIM5D model within the BIM system. This functionality proves valuable when managing design change orders and site visa orders. Additionally, managers can generate a work change and visa model that establishes a connection between the original BIM5D model and associated technical approval documents pertaining to changes and visas. The BIM5D platform facilitates the integration of comprehensive data pertaining to the whole lifecycle of engineering projects, enabling systematic storage and intelligent extraction of information. The utilization of the BIM5D platform enables project budgeting personnel, technical personnel, and procurement personnel to conveniently access, document, and modify cost-related data at any given time and location. Consequently, this effectively addresses the issues of insufficient data and data latency encountered in the area of construction cost management.

2.3.2 Lower costs

In accordance with Revit China [14], the BIM5D platform is a comprehensive tool for visualising project information in three dimensions. It enables all stakeholders to access and interpret the data embedded within 2D drawings. Additionally, the platform facilitates the identification and resolution of design conflicts by conducting collision checks within the 3D model. This feature is particularly valuable as it allows for the detection and optimization of design issues that may be challenging to identify solely through 2D drawings. The cost-related data available in the BIM5D platform offers managers a foundation for making informed decisions on costs. This includes the ability to build cost plans, minimise resource waste during construction, prevent under-resourcing, alleviate logistics pressure, and avoid excessive storage. Ultimately, these features enable the achievement of efficient resource management. The BIM5D platform incorporates integrated progress cost information, enabling real-time monitoring of expenses during the construction simulation process. This functionality also allows for the modelling of fund utilization, facilitating the development of a well-founded capital plan and providing a basis for fundraising and coordination efforts.

2.3.3 Higher efficiency

The efficiency of construction management is expected to improve as it transitions from a reactive approach to a proactive one. Additionally, the utilization of BIM5D offers two additional parameters, namely time and cost, compared to the 3D model. This expanded functionality enables more effective project management. The utilization of BIM technology enables the creation of a comprehensive technical model. Construction managers utilize the BIM 5D information integration platform to analyse various data points, including building construction time, construction floors, component quantities, and list quantities. This analysis enables them to derive the necessary material quantities and enhance the efficiency of material control. By effectively managing the overall project material plan, construction managers can optimize material utilization and enhance project efficiency [14].

2.3.4 Detailed management

BIM 5D refers to a three-dimensional (3D) model that is utilized for the purpose of cost management. In adherence to the prescribed construction timeline, the issue is addressed by focusing on the utilization of raw materials and the compilation of construction volume data. Firstly, a more precise building information model is developed, particularly for intricate structural components, to enhance the accuracy of work volume statistics. Secondly, the construction process is dynamically simulated to enable better management of labour, materials, and construction machinery consumption [14].

2.3.5 Fewer disputes

Ahmad [15], assert that the extensive data held in Building Information Modelling (BIM) poses challenges in terms of effective management and application. Consequently, construction personnel's understanding of the project is limited to certain characteristic data, leading to deviations in the control of the building project. The implementation of BIM technology enables the effective classification, management, and integration of extensive data within construction projects. Incorporating cost data and construction progress data in an organic manner throughout the construction process enables construction managers to effectively execute building construction projects, while facilitating cost managers in accurately tracking quantities, changes, and cost data to ensure data precision.

2.3.6 Visualisation of data

In their study, Erol [16] conducted an analysis of the utilization of data visualization in the BIM model. Their approach involved establishing interactivity and feedback mechanisms among the many components of the BIM model, hence enabling its continuous application throughout the entirety of a project. The BIM5D information integration platform offers a practical solution for effectively partitioning the construction surfaces in a building project. It enables the visualisation and simulation of theoretical labour and cost analysis, thereby mitigating the challenges associated with cost coordination and conflict arising from multiple cross-processes and subcontracting teams operating on the work surface. The utilisation of the BIM5D platform's three-dimensional visualisation feature enhances the efficacy of communication among construction managers, particularly in addressing intricate matters like construction site dynamics and the arrangement of construction equipment. Upon acquiring a comprehensive comprehension of Building Information Modelling with a 5D dimension (BIM5D), the subsequent discussion has to provide a succinct overview of its significance and associated benefits as delineated in Table 2.

Table 2
Importance and Benefits of BIM5D

Importance and Benefits of BIM5D	Reference
Easier data management	[17]
Lower costs	[17]
Higher efficiency	[18]
Detailed management	[19]
Fewer disputes	[20]
Visualisation of data	[20]

2.4 Factors That Hinder the Development of BIM5D Technology in China
2.4.1 China's culture of tight schedule

According to the findings of Yang [21], the ongoing construction projects are characterized by a pull production approach, wherein the main production concept revolves around meeting the demand of the service industry. Managers typically do not prioritize the integration of BIM5D (data-driven) at the core of project completion considerations. Instead, their primary focus lies on commercial profitability, followed by the timely completion of the project. From the perspective of the project management, any additional expenditure is perceived as a cost, hence it is a prevalent occurrence within the construction sector for several development sites to adhere to project timelines. According to this system, the key attribute of the practitioner is characterized by diligent effort and perseverance, along with the capacity to generate financial gains from a business standpoint to support the project. In this paradigm, BIM5D also functions as a project service. In essence, the role of a BIM designer encompasses operating three-dimensional software, addressing design issues, conducting business calculations, expressing bid effects, comprehending design intent in construction, obtaining precise data through measurement and alignment, and resolving challenges related to complex customized processing parts that cannot be handled by conventional processing methods. Thus, the BIM designer serves as a technician who tackles these aforementioned problems. It is indisputable that the resolution of these issues necessitates the possession of proficient technical expertise. However, the recurrent, dynamic, and time-sensitive nature of the necessity for regular troubleshooting frequently impedes a BIM designer's ability to contemplate their potential capabilities and optimal efficacy. In the context of a fast-paced work environment characterized by strict deadlines, BIM designers may find themselves preoccupied with their tasks, leaving little room for contemplation or reflection.

2.4.2 Data fragmentation

The construction industry has a lengthy historical background and a slow rate of industrialization, which has contributed to a prevalent absence of data-driven thinking among practitioners. These individuals are accustomed to operating without scientific planning, relying heavily on manual labour and ad hoc approaches. Consequently, this has resulted in fragmented collaboration across different work domains. The nature of the forthcoming message is difficult to ascertain, as it could potentially encompass a complaint, a conflict, a reminder, or a valuable metric to guide future efforts. The proliferation of information through unreliable interfaces, the evolving design criteria, the need for timely delivery of output, the absence of standardized BIM5D delivery protocols downstream, the fragmentation of BIM5D tasks across multiple projects, and the interactive nature of BIM5D results presentation all necessitate attention and resolution. On the other hand, the collaboration between building and construction firms and design institutes, fabrication plants, and other entities in the supply chain is frequently driven solely by business considerations, without taking into account technical management aspects. The technical teams of both parties are characterised by their high mobility and frequent engagement in project-based contracts, with a heavy reliance on the unique competencies of team members. The conventional technical management model has the potential to become increasingly complex in the context of the construction industry, resulting in a significant reduction in the effectiveness of design departments inside enterprises, resembling sweatshop-like conditions [22]. The phenomenon of data fragmentation presents both challenges and opportunities. The individual or entity that can assume a leadership role in resolving the issue of fragmentation will have the opportunity to gain a strategic advantage.

2.4.3 Underfunded

Yi Zhihang [23], posits that a current impasse exists in the field of project management, wherein practitioners are hesitant to invest more in BIM5D until they witness tangible results. Additionally, BIM5D designers face the arduous challenge of navigating complex jobs without sufficient financial incentives. The cause of the impasse stems from the client's decision to procure construction services without first specifying a concrete design product, resulting in a lack of detailed specifications. Simultaneously, project managers encounter constraints and uncertainties that hinder their ability to confidently invest in a particular project including BIM5D designers. Likewise, BIM5D designers are unable to provide a definitive assurance regarding the extent of their positive impact on the project due to the prevailing uncertainties.

2.4.5 Low market acceptance

Despite the numerous drawbacks associated with the utilization of a 2D working model, including limited visual representation, inadequate data analysis capabilities, and suboptimal information exchange among different professions and connections, it is worth noting that this approach has been extensively employed in China for several decades. Consequently, the industry and enterprises have independently devised a range of solutions to address the aforementioned challenges. The expenses and hazards involved with the implementation of BIM5D are comparatively higher than those associated with its reinvention, leading many organisations to maintain their reliance on the CAD working paradigm. The lack of awareness and understanding among building owners and designers regarding the potential financial benefits of implementing BIM5D, coupled with the inadequate assessment and recognition of the costs and advantages of 3D design in the market, has led to a lack of interest and promotion of BIM5D in the early stages of construction projects. Consequently, the widespread adoption of BIM5D throughout the industry chain has been hindered. The widespread implementation of BIM5D across the industry chain poses challenges [24]. Simultaneously, Chinese projects typically exhibit abbreviated design cycles, stringent deadlines, and temporal limitations, so impeding designers from adequately assessing the potential benefits of BIM5D in the design process. Moreover, the limited timeframe further restricts the allocation of resources for pertinent BIM5D training.

2.4.6 Low level of localization of BIM5D software

The application and development of BIM software in foreign nations surpasses that of China due to prior research on this issue. This is attributed to the inherent reliance of 3D design on building elements and the object-oriented foundation on which BIM software is built. China has been relatively slow in adopting the BIM concept. The country primarily relies on a fixed Computer-Aided Design (CAD) work mode and a specific set of development procedures. This lack of emphasis on the import of 3D concepts has led to a heavy reliance on foreign software for the 3D aspects of building elements. Consequently, many enterprises in China have had to develop their own software, which has inevitably increased both the cost and difficulty in recent years, numerous Chinese research institutions have dedicated significant human and material resources to the development and adaptation of Building Information Modelling (BIM) software within the country. Notably, Tsinghua Swire, Glodon, and Luban BIM software have emerged as prominent leaders in the field of localised BIM software.

2.4.7 Poor promotion environment

According to Li [25], the term "promotion environment" in this context pertains to the lack of comprehensive promotion policies implemented by the government for firms involved in the project, spanning from the upstream to the downstream. The implementation of upstream units, particularly if not pursued with sufficient vigour, presents challenges in disrupting the current operational framework. Furthermore, the absence of domestic case studies on the operational mode of BIM limits the availability of reference materials. The diversity of domestic design units, building construction companies, and other business levels has emerged as a significant impediment to the successful application of Building Information Modelling (BIM). There are several obstacles that impede the adoption of Building Information Modelling (BIM) in China. One significant obstacle is the lack of motivation among experienced designers to acquire proficiency in sophisticated and novel software. Additionally, the substantial burden of model maintenance resulting from design modifications and drawing adjustments throughout the construction phase further contributes to hindrances in the implementation of BIM in China. In summary, the introduction of novel technologies is typically accompanied by challenges, and BIM5D is no different. However, it is indisputable that BIM5D technology has significantly impacted the construction sector, and its prospective advancements hold promise for the future. Upon acquiring a comprehensive comprehension of Building Information Modelling with a 5D dimension (BIM5D), the subsequent discussion has to provide a succinct overview of the factors that hinder the development of BIM5D technology in China in Table 3.

Table 3
Affect Factors of BIM5D

Affect Factors	Reference
China's culture of tight schedule	[24]
Data fragmentation	[26]
Underfunded	[26]
Low market acceptance	[26]
Low level of localisation of BIM5D software	[26]
Poor promotion environment	[24]

2.5 The Successful Implementation Strategy for BIM5D
2.5.1 Expand economic incentives

According to a study conducted by Revit China [14], economic incentives emerge as the predominant approach for fostering the adoption of BIM5D technology within organizations. It is recommended that the government employ a range of policies aimed at providing increased economic incentives to firms that adopt BIM5D technology. These policies may include granting greater weightage to projects that incorporate BIM technology in construction evaluation, as well as offering specific economic rewards to projects that get awards. Furthermore, the construction units, serving as the central component of project management, possess greater authority in decision-making pertaining to the project. It is imperative for the government to provide guidance to these units in promptly acknowledging the significance of BIM5D technology throughout the entire construction life cycle. This entails offering economic assistance to collaborators who adopt BIM5D technology and facilitating its implementation in the comprehensive management of construction projects.

2.5.2 Talent training

Xue Jie [27], the author posits that the crucial component for the successful implementation of BIM5D in construction companies lies in the presence of skilled individuals specializing in BIM5D. These individuals referred to as BIM5D talents, play a pivotal role in ensuring the effectiveness of BIM5D implementation. Construction enterprises should implement a systematic approach to organising training programmes for their personnel, focusing on imparting fundamental knowledge of BIM5D and software operation. This initiative aims to enhance the operational proficiency of personnel in applying BIM5D in real-world projects, while also bolstering the talent pool in BIM5D technology. Simultaneously, it is imperative to establish a scientifically and logically sound mechanism for nurturing talent, enhance the innovative capabilities of BIM5D professionals, and achieve the optimal distribution of BIM5D talent resources. This will facilitate the effective implementation and widespread adoption of BIM5D, thereby gradually enhancing the scope and depth of quality and efficiency within the construction industry.

2.5.3 Implementing pilot projects

In the context of BIM5D implementation, it is viable to initiate the process by doing a pilot project, wherein a designated small team is granted the opportunity to experiment with the implementation of BIM5D on a specific project. According to Chung (2021) the objective of this study is to investigate the utilisation of BIM5D technology in project management and to analyse its application route in conjunction with the implementation of a specific project. The study aims to identify the key aspects of BIM5D technology application and implementation experience, and subsequently establish a standardised approach for implementing BIM5D in future projects following successful outcomes. Adopting this approach allows for sufficient time to identify unforeseen errors and address them prior to the full implementation of the project, thereby mitigating potential significant consequences. Additionally, it facilitates the enhancement of the BIM5D application's value, serving as a prominent and illustrative example for the advancement of BIM5D technology within the enterprise. Consequently, it effectively accelerates the organization's rapid development.

2.5.4 Data management

The BIM5D dataset encompasses data from several domains throughout all stages of the building life cycle. The question at hand pertains to comprehending and analysing this data. Vishnu Prasad [29] asserts that data plays a crucial role in enhancing productivity and minimizing rework, so significantly bolstering the core competitiveness of firms, and enabling them to outperform their rivals in terms of efficiency and intelligence. The administration of BIM5D model data facilitates the ability to track information in real time, allowing for quick and accurate retrieval of the relevant data stored in the system database at any given moment. The optimisation of BIM5D technology necessitates the collaborative engagement of BIM5D software developers, users, and other stakeholders. This collective effort is essential to uphold a data-centric operational approach and to consistently incorporate feedback and rectifications during the implementation process. By accumulating historical data and fostering gradual refinement, a standardized communication process can be established between developers and users. This standardised process aims to facilitate efficient decision-making, thereby enhancing project quality, minimising resource allocation, and augmenting project profitability. Additionally, the implementation of project big data by firms facilitates the computation of project investment, monitoring of progress, and assurance of human safety within the context of big data.

2.5.5 Establishing a BIM management system

The implementation of BIM5D extends beyond just tool and software operations, including all departments and positions within a company. This pertains to the procedures for company management as well as the development and evaluation of the hierarchical progression of skilled individuals. According to Wang [30],the assurance of a configuration system and the provision of software and hardware environment are deemed necessary. Moreover, the slow adoption of BIM in the construction industry may also be attributable to users' awareness, perception of utility, compatibility with the new technology (BIM), and fear of change. In order to increase awareness of BIM in the construction industry, it is necessary to provide a comprehensive comprehension of the integration process [31]. Hence, it is imperative for organizations seeking to implement BIM5D to develop an appropriate BIM5D management system. This may be achieved by the recruitment of a proficient BIM5D team, conducting preliminary BIM5D projects, utilizing the enterprise's BIM5D team as a foundation, and aligning with the organization's specific circumstances. Upon acquiring a comprehensive comprehension of Building Information Modelling with a 5D dimension (BIM5D), the subsequent discussion has to provide a succinct overview of its successful implementation strategy for BIM5D as delineated in Table 4.

Table 4
The Successful Implementation Strategy for BIM5D

The Successful Implementation Strategy for BIM5D	Reference
Expand economic incentives	[32]
Talent training	[33]
Implementing pilot projects	[33]
Data Management	[34]
Establishing a BIM management system	[34]

3. Methodology
3.1 Research Approach and Strategies

This study employs qualitative research methodology, which involves examining only a small and purposefully chosen sample of individuals. Unlike quantitative research, qualitative research does not rely on statistical significance. Instead, it relies on the researcher's expertise, perceptiveness, and appropriate technological tools to gain valuable insights into the behaviour, motivations, and potential impact of the research subjects, among other factors. The qualitative approach encompasses the gathering and examination of non-digital data, such as textual, video, or audio materials, with the aim of comprehending thoughts, opinions, or experiences. The qualitative technique is employed to get insight into individuals' subjective experiences and perceptions of the world. Although numerous qualitative techniques exist, they are characterized by their flexibility and emphasis on preserving nuanced interpretations during the data analysis process.

Case studies possess a great degree of adaptability, allowing researchers to tailor them to their own needs and align them with the nature of their research questions. Various methods can be employed to gather data, such as conducting interviews, organizing focus groups, examining paperwork, engaging in direct observation, and employing participant observation. Hence, the utilization of the case study methodology is employed while doing a comprehensive examination of an individual, a collective, an institution, or a particular undertaking, with the purpose of bolstering the researcher's aims. The case study approach, being limited by its reliance on a single feature, leads to findings that are specific to a particular event rather than generalizable. Hence, the present study aims to evaluate the constraints and viability of the software in relation to cost management, employing the Glodon BIM5D as a case study and including real-life projects conducted by Glodon. Consequently, the study's findings are specifically centred on the Glodon BIM5D software, with a comprehensive examination facilitated by employing a case study methodology. Therefore, it is justifiable for this research to utilize this method in order to conduct a comprehensive examination of the tangible advantages and importance experienced by projects through the utilisation of Glodon BIM5D in China, as well as how these challenges are effectively managed in real-world scenarios.

3.2 Selection of Case Studies

Case studies are a method of gathering comprehensive information regarding a specific business phenomenon, which may occur in either comparable companies or environments, or in a singular and distinctive case, such as an individual, organization, or setting. Additionally, the project context serves as the foundation for the inception of the project concept. In order to maximize the likelihood of a successful feasibility study, it is imperative that the individual conducting the study possesses an in-depth understanding of the project's context. Additionally, it is crucial for the individual to furnish a meticulous description of the project's scope, whether it pertains to a product or service. Furthermore, it is essential to substantiate the rationale behind the project sponsor's interest in the undertaking. The identification of the project's context is crucial as the presence of limitations can vary across different initiatives. Consequently, this will enable the researcher to evaluate the correlation more effectively between the two aims. This research selected two projects that are currently being pursued by a QS company in order to facilitate more effective comparisons.

Table 5
The background of Projects

No.	Project 1	Project 2
1	8 Buildings	22 Buildings
2	440 Units	2146 Units
3	Two types of unit layouts designed with different building sizes	Four types of unit layouts designed with different building sizes
4	Greenery ratio of 32.4%	Greenery ratio of 35%
5	Total floor area of approximately 84,000 sqm	Total floor area of approximately 468,000 sqm

Table 6 demonstrates that both the high-rise projects with big floor areas and the low-rise projects with small floor areas are utilizing Glodon BIM5D for cost management and comprehensive cost management throughout all project phases. Both of the projects that have been chosen are residential community projects with a significant budget allocation. Furthermore, both initiatives encompassed substantial capital transactions and involved intricate and extensive undertakings, necessitating the active participation of stakeholders from diverse disciplines, organizations, and backgrounds.

In the context of this research endeavour, it is deemed that semi-structured interviews present the most suitable approach for the acquisition of data. According to Wolff *et al.,* [35] semi-structured interviews deviate from the predefined content and structure outlined in the initial guidelines. These interviews allow for flexibility in expanding the interview content based on ongoing interaction and adjusting the order of the interview questions based on the evolving conversation. Semi-structured interviews often follow an interactive framework characterized by an exchange of information. The primary research method employed in this study is semi-structured interviews. The interviews were carried out by the researcher with a semi-structured question-and-answer methodology, employing both telephone and face-to-face interviews. The interviews were categorized into two distinct roles: the interviewer and the interviewee. The interviewees were provided with a clear explanation of the goal of the interview prior to its commencement, and consent was sought beforehand. All of the interviewees utilized Glodon BIM5D as their primary tool for cost reduction.

3.3 Participants

A total of 6 people who were users of Glodon BIM5D participated in the interview procedure, as indicated in Table 6. It is noteworthy that all of these participants had previously undergone an advanced training course conducted by the Glodon Learning Centre. In order to be eligible for enrolment in the advanced course, it was necessary to have fulfilled the prerequisite of successfully completing a tender project utilizing Glodon software. All participants possessed a minimum of 3 years of experience with Glodon, which met the criteria for their inclusion in the interview process. Furthermore, each participant had been awarded the prestigious China Level 2 Engineer certification. The individuals originated from different A cost departments, separate major contractor cost departments, and two third-party consultants specializing in quantity surveying. The interviews encompassed professionals from the construction sector who are currently engaged in Building Information Modelling (BIM) projects, with a subset of individuals possessing a minimum of fifteen years of practical expertise in this domain. A total of six participants, drawn from two distinct projects, took part in the in-depth interview sessions. Participants 1, 2, and 3 were involved in the study denoted as P1. Participants 4, 5, and 6 were involved in the second phase of the study (P2).

Table 6
The profile of respondents

Expert ID	Type of Firm	Position	Working Experience (Years)	Glodon BIM 5D Experience (Years)	BIM Projects Involved
R1 (P1)	Party A	Cost Manager	10	8	6
R2 (P1)	Contractor	Quantity Surveyor	7	7	5
R3 (P1)	Consultant	Quantity Surveyor	15	10	8
R4 (P2)	Party A	Cost Manager	25	10	8
R5 (P2)	Contractor	Quantity Surveyor	20	8	10
R6 (P2)	Consultant	Quantity Surveyor	10	10	6

3.4 Research Flow

The research plan serves as the preliminary phase in addressing pertinent matters. The research commences by examining contemporary concerns pertaining to the construction sector through a comprehensive review of diverse sources, including scholarly publications, articles, newspapers, and magazines. A thorough examination of pertinent academic resources from both domestic and international sources is undertaken to analyse the contextual background and significance of the research, as well as the existing state of research in both local and global contexts. The fundamental basis for determining the primary research directions and contents is derived from referencing the scholarly findings of previous researchers. The researcher discovered areas of interest that are pertinent to their area of expertise. Subsequently, they researched a specific topic, which was further explored in a subsequent stage. This led to the development of a concise problem statement. The research subsequently formulated its targets and objectives, so delineating the extent and importance of the study. Through an examination of the utilization of BIM5D technology in the subject of cost control throughout the construction phase, the significance of BIM5D technology within construction businesses will be enhanced, hence elevating the degree of cost management within construction organizations. Figure 1 depicts the sequential flow of the research approach, which serves as the basis for this study.

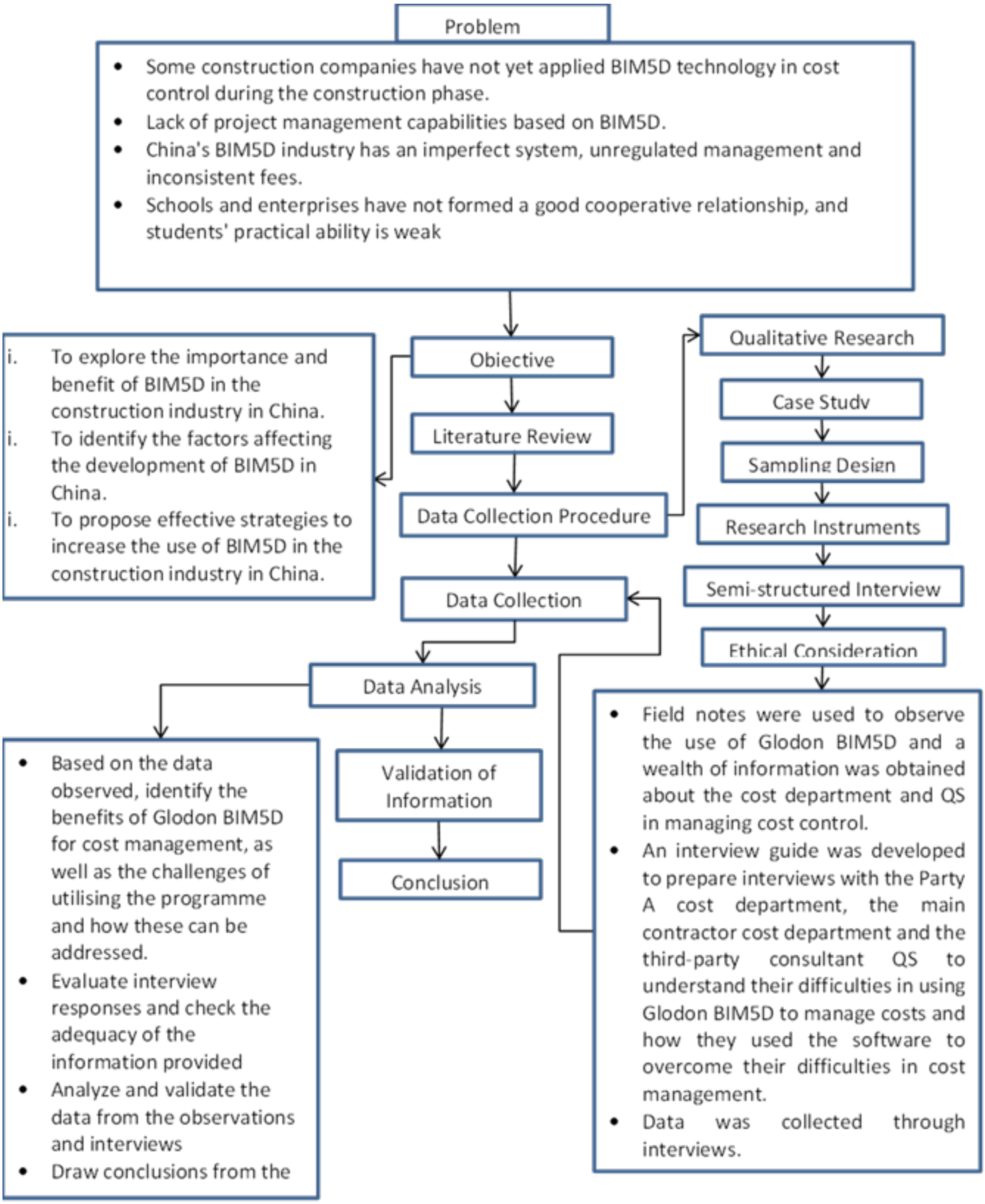

Fig. 1. Flow chart of research methodology

4. Results and Discussion
4.1 Results

The relevant subjects deemed significant to the outcome of this study have been identified and analysed in this section. The topics derived from the interviews are shown in Table 7.

Table 7
Items derived from the data collection

Objectives	Items	Respondents					
		R1	R2	R3	R4	R5	R6
Importance & Benefit	Easier Data Management	√		√			√
	Lower Costs	√	√	√	√	√	√
	Higher Efficiency	√	√	√	√	√	√
	Detailed Management	√			√		
	High Mobility (new finding*)	√					
	Visualization of Data			√			√
	Less Disputes		√		√	√	
Affect Factors	Transformation Barriers (new finding*)	√	√	√	√	√	√
	Software and Technology Issues (new finding*)	√	√	√	√	√	√
	Lack of Collaborative Environment			√			√
	Economic Barriers	√	√		√	√	
	Organizational Barriers				√	√	
	China-specific Factors	√			√		
Effective Strategies	Improving Talent Development	√	√	√	√	√	√
	Supporting Policy Guidance	√	√		√	√	
	Strengthen Industry Exchanges (new finding*)	√				√	
	Software Developers to Improve Technology	√	√	√	√	√	√
	Develop Standards				√		

Regarding the importance and benefits of BIM5D, all interviewees agreed on cost reduction and efficiency, with R6's view.

"Because BIM5D has a powerful database function, finding data can be done quickly. It also enables aggregation and analysis of data to be completed in a short time, making data processing time efficient and quick."

By adopting BIM5D, the majority of respondents agreed that it makes data management easier. The key feature of reducing disputes was also one of the performance impacts repeatedly cited by the majority of respondents. R3 stated:

"Whereas with the advent of BIM5D, this large amount of data can be categorized and managed as well as applied, and the control of the whole project can be more accurate. "

Both R1 and R4, as cost department managers at management level, refer to the more detail management that BIM5D brings, their view being that:

"The project team has a smoother understanding of pre-construction design, schedule planning, cost information and can make better decisions about funding based on the former information."

Only R1 explains his own unique high mobility perspective that differs from the other respondents:

"With BIM5D, the person in charge can track and monitor the work of each department and control various details, resulting in better communication and finer management. In addition, it is easy to manage and, with internet access, it is highly mobile, allowing work to be carried out through BIM5D at any time and from anywhere".

Respondents were asked about the factors that prevented them from using BIM5D in their respective projects. Different respondents explained this inhibiting factor from different perspectives. The main barriers were summarized in six categories: barriers to transition, software and technology issues, lack of a collaborative environment, economic barriers, organizational barriers and China-specific factors. All Respondents agreed that transformation barriers, software and technology issues were the main challenges.

R3's thoughts as QS, which has successfully undergone the transition, are:

"BIM5D is an innovative piece of software, and many of its concepts differ from those of conventional software. Massive numbers of architects and engineers in China are relearning modelling, and the process of drawing is also the process of modelling, which is as challenging as you can imagine. It is acceptable for younger architects, but many older architects may never learn it."

R4 shares some elements of Chinese identity:

"Party A has too much power and Party B is completely subordinate. The final result of BIM is a holographic model, which is equivalent to an extremely detailed and complete set of construction drawings, and the frequency of changes made by the Chinese party A is clearly a waste. In this environment, the otherwise efficient BIM may be far less efficient than traditional design methods. In addition, the efficiency and transparency of BIM has also made it possible to hide some of the fishy areas that could have been known to everyone."

Respondents were asked how they would use effective strategies to promote the use of BIM5D in China. Different Respondents gave their views from different perspectives. The author has grouped the main strategies into five: improving talent development, supporting policy guidance, enhancing industry communication, software developer promotion and developing standards to support it. All Respondents agreed improving talent training and software developer promotion are effective development strategies at present. R5 believes in better communication and publicity. Here's what he thinks:

"There should be more communication and discussion between the internal units of the company, and we should find the gap between us and the outside through communication and through learning. Strengthen the publicity of the BIM5D achievements of each highlight feature project to create more industry conferences or attend and speak at forums. Increase the efforts to create awards, strengthen the summary of the results of the entries to improve the quality of the entries, and enhance the level of BIM5D application of the company through creating awards. While applying and practicing BIM5D, benchmarking samples should be set up to enhance industry communication and learning."

The introduction of emerging technologies needs to be incentivized and supported by policy, and R2 agrees, sharing his view that:

"The government should develop a number of regulations to provide additional financial incentives to businesses that use BIM5D technology, such as giving projects that use BIM technology more weight in construction review and providing specific financial rewards for award-winning projects. This will enable partners using BIM5D technology to do so and will allow for the application of BIM5D technology in the entire process management of construction projects."

5. Discussion

The objective of this study is to provide a thorough comprehension of the anticipated outcomes, challenges, and possible approaches for private-sector organizations that are initiating or considering the execution of a BIM5D project within the construction industry of China. This section covers the findings of the study, focusing on the advantages of BIM5D in terms of cost control. It discusses the benefits that users of BIM5D consistently experience and highlights the advantages that have been scientifically identified and documented in published literature. The advantages of enhanced productivity, fewer conflicts, modifications, and cost reductions are commonly experienced. Additionally, a novel advantage of BIM5D has been recognized, namely its exceptional mobility and accessibility through internet connectivity.

The primary barriers to the widespread implementation of BIM5D can be attributed to the challenges associated with transitioning to this technology and the inherent concerns pertaining to software and technology. In essence, the key barriers revolve around software-related challenges and ideological considerations. The traditional construction sector exhibits a prolonged resistance towards the use of BIM5D. The costs associated with software development are undeniably high, owing to the inherent expense of technology and innovation. This expense includes the purchase of software, the provision of hardware equipment, and training. Consequently, numerous construction companies cannot afford to implement BIM 5D within their organisations due to the aforementioned factors [36]. There is a requirement for financial assistance to help both software developers and users of BIM5D. Despite the government's implementation of certain policies aimed at promoting BIM5D, their execution has been inadequate, resulting in a lack of effective financial assistance reaching software developers and users of BIM5D. In addition, a recent study by Jia [37]'s provides a significant analysis of this concern. In this regard, it is imperative for the government to thoroughly deliberate on the provision of essential supplementary financial support to facilitate the advancement of Building Information Modelling (BIM) in its entirety within the construction sector, as well as in the context of BIM5D.

Furthermore, it is important to note that the presence of a strategy alone is inadequate in the context of the industry. To enable the smooth functioning of BIM5D, a thorough implementation standard is necessary. The fundamental goal of implementing BIM5D is to develop a cohesive and model-driven collaboration within the industry, with standards playing a pivotal role in achieving this purpose. This encompasses various aspects related to the organisation and arrangement of distinct branches, delineation of roles and responsibilities, implementation of managerial protocols, and development of human resources. It is vital for the organization's BIM5D team to undertake the establishment of a BIM5D management system that is adapted to the specific circumstances of the organisation. This initiative is also supported by [38].

Moreover, in light of the findings of the research, it is recommended that BIM5D talent training programmes and software developers boost their technical skills. The significance of delivering instruction on BIM5D to students in an academic setting cannot be emphasised, since it has been recognised that transforming individuals' perceptions is a challenging endeavour. By adequately equipping students with sufficient training and education prior to their integration into the construction industry, it is likely that the construction sector will see favourable outcomes in the future. Since technology necessitates hands-on skills, the government must identify the appropriate tools to apply to the specific field of study and human aptitude. The simulation software is novel and requires an investment of millions of dollars. Smart simulator technology can be a solution for certain engineering disciplines, but every technology must account for the training costs and environmental impact. The government, particularly the Ministry of Education, must act swiftly; graduates will be a new generation able to acquire the skills and meet updated industry requirements. Restructuring the programme with education based on outcomes is an alternative solution [39].

Moreover, it is expected that the integration of ongoing training initiatives would bolster organizational culture in the near future, as a result of the combined efforts between corporate entities and educational establishments [40]. Moreover, it is feasible for individuals to gain expertise from technologically sophisticated BIM5D enterprises in China and other countries. This will facilitate individuals in improving their comprehension, participating in ongoing exploration and innovation, addressing the current limitations of Chinese BIM5D software, developing new competencies, and actively engaging in both domestic and international competition within the context of a market-driven economy.

The proposed strategy aims to provide tailored guidance to the Chinese government and BIM5D-based project groups, facilitating the proper implementation of BIM5D for their projects. This implementation would afterwards lead to enhanced cost control. The proposed implementation choices outlined in this study will facilitate the attainment of this objective since there exists a requirement for proficient support in the integration of modern techniques such as BIM. Moreover, this study will provide a more comprehensive understanding of BIM technologies that may be utilized in upcoming projects to enhance efficiency in terms of time, cost, and quality. Additionally, it will explore a diverse array of methodologies that are specifically relevant to particular problem areas. The government may prioritise these significant challenges and develop a strategy for implementing BIM5D to effectively tackle them. The proposed technique has the potential to yield benefits for projects of different scales and natures, as well as for the private sector and other countries. However, it may require certain adaptations to align with the specific objectives of their own BIM5D initiatives.

6. Conclusion

Firstly, this study contributes to the current body of knowledge on BIM performance by highlighting cost reduction and efficiency as the primary benefits emphasized by all participants in the interviews. The discovery of a novel element, referred to as high mobility, which integrates three distinct platforms - mobile, PC, and browser - represents a significant advancement in the field of BIM5D. Next, the research findings indicate that the most significant challenges in utilizing BIM5D are the challenges encountered throughout the transition process, as well as the software and technology-related concerns. Furthermore, the research outcomes have shown novel challenges encountered during the implementation of BIM5D. These challenges encompass the complexities associated with the integration of cost department personnel, as well as the complications arising from software development and technological concerns. The subsequent significant discovery of the study pertains to potential suggestions for the implementation of BIM5D. Specifically, it is recommended to develop a comprehensive BIM5D implementation strategy at the governmental level in order to effectively plan and address organisational aspects of BIM5D management.

Collaborative training and BIM5D education are frequently mentioned as the primary strategies for addressing the issues associated with BIM5D. Additionally, the results suggest that there is a need for government intervention in order to facilitate the adoption and implementation of BIM with a focus on the integration of time (4D) and cost (5D) dimensions within the construction industry. Hence, governmental entities possess the ability to utilize success indicators from foreign nations as reference points for the local integration of Building Information Modelling with 5D capabilities (BIM5D). This may involve the implementation of BIM5D standards, the provision of pilot studies, and the execution of comprehensive plans, among other measures. Furthermore, the research findings suggest that academics possess a significant responsibility in developing appropriate frameworks for the adoption of BIM5D within the Chinese construction industry and practice. Likewise, scholars have now obtained a substantiated understanding of the performance of BIM5D projects, the challenges they encounter, and potential solutions to overcome these hurdles. Additionally, they have developed strategies to enhance the adoption and implementation of BIM5D. Consequently, researchers can now delve into unexplored facets of this subject matter.

Based on the findings of this study, there are a number of potential future research topics that could contribute to the sector's development. The implementation of an improved training system for individuals, spanning from their educational phase to their professional integration, along with the incorporation of government regulations to address BIM5D challenges encountered during project planning, and the ongoing refinement of government standards in real-time is crucial. Additionally, future research should employ quantitative research methodologies to empirically investigate the highlighted performance variables and problems. This will contribute to a deeper and more nuanced comprehension of the subject matter. A primary limitation of the study is that the perspectives expressed are derived from a small group of competent individuals, which may not adequately represent the comprehensive perspectives held by experts and the industry as a whole. Individual perspectives based on individual opinions are conveyed. A significant proportion of BIM5D users lack the necessary credentials, thereby diminishing the authority of their perspectives.

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