Analysis of the current status and comprehensive ap plication research on BIM technology in construction cost management

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Abstract: With the advancement of national economic strategy, the construction process has encountered an escalation in problems and challenges, thereby emphasizing the significance of cost management. The current management of construction costs is confronted with numerous challenges, encompassing limited visualization capabilities, inadequate collaboration among diverse professions, isolated decision-making processes, and a lack of automated procedures. The emergence of BIM technology has brought forth the possibility to address these challenges, offering a green, efficient, and sustainable solution. The comprehensive implementation of BIM technology in cost management enables the refinement of project cost management. By conducting an in-depth analysis of the current state of civil engineering construction cost management, this paper proposes a comprehensive approach to applying BIM technology, which offers scientific and technical means for addressing these issues and serves as a catalyst for generating valuable insights.

1. Introduction

With the advancement of national economic warfare, the continuous regulation of pertinent policies within the construction industry, escalating challenges in construction technology, and a growing scarcity of construction resources, various issues within the construction process are increasingly prevalent. These include but are not limited to cost control, construction quality assurance, efficiency optimization, as well as ensuring safety for all personnel involved[1]. The new environment has a significant impact on project management in various construction enterprises, with cost management being one of the most crucial factors. In the traditional process of construction cost management, several key issues need to be addressed: limited visual capabilities, lack of collaboration, isolated decision-making, and the absence of automated processes[2]. The current cost management model has proven inadequate in meeting the demands of social development. However, the emergence of Building Information Modeling (BIM) technology presents an effective solution to this problem. BIM technology serves as a proficient means of cost control, characterized by its promotion of green practices, efficiency, and sustainable development. It can be utilized to enhance the project construction process, organizational structure, and practical technology while improving overall management capabilities and cost control proficiency[1]. This paper proposes a cost control strategy based on an analysis of the current state of civil engineering construction cost management, emphasizing the full and effective implementation of construction project management. Additionally, it introduces the application of BIM technology and digital twin in cost management.

2. The analysis of the current cost status in civil engineering construction

2.1.Overview of Construction Project Management and Cost Management

2.1.1 The concept of managing construction costs

The cost management of construction projects plays a pivotal role in reflecting the overall project management level amidst the rapidly evolving domestic economic landscape, with cost management being its most crucial component. Construction cost management is a management means to minimize project costs and maximize economic benefits through planning, control, accounting, and analysis of various resources, materials, equipment, manpower, and other inputs in the construction process. The classification primarily consists of:

1. Cost plan: Before the project is implemented, the project cost budget and investment estimate are prepared to provide a cost basis for the construction of the project and ensure that the project investment is within a reasonable range.

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2. Cost accounting: The process of detailed reco-rding, statistics, and analysis of all costs incurred during the entire construction process.

3. Cost control: In the construction process, through the supervision and adjustment of project progress, resource use, site management, etc., to ensure the expected cost effect.

4. Cost analysis: Based on the cost accounting data, through in-depth analysis and research on the project cost, find out the reasons for high or lower costs and possible risks, and take appropriate measures to adjust in time.

Standard and effective construction cost mana-gement is conducive to reducing costs, ensuring project quality and schedule, and making reasonable use of resources. At the same time, improves the construction enterprises' mastery of their management work, and provides a scientific and real basis for internal performance assessment.

2.2.Cost management status and problem analysis

In the current construction industry, cost management has been widely recognized and applied. However, in practice, traditional cost management still faces many problems. These include poor visualization skills, lack of collaboration among specialties, isolated decision-making, and lack of automated processes. At the same time, the project manager's cost consciousness is weak, and the knowledge of cost management technology is insufficient and limited. The above problems are mainly related to the assistive technology used in the project, the quality of information and data, and the collaborative communication within and outside the project [3].

2.2.1 Traditional cost management associate technology is backward

Traditional cost management using computer-aided design (CAD) to draw 2D drawings can not be visualized expression so project personnel can not understand the project deeply. Traditional management uses manual, labor, and time-intensive work such as measurement, data entry, costing, and documentation. Lack of automated processes, inability to cope with changes, lack of cost data review, and use of basic division of labor systems are the main reasons for the low authenticity of cost estimates; And data loss also affects the effectiveness of cost management. In traditional cost management, we only pay attention to labor, materials, and equipment, but neglect management expenses and risk costs, which leads to incomplete collection of cost data. Secondly, traditional management mainly relies on manual data collection and updates, and the frequency and timeliness of data updates often cannot meet the actual needs, resulting in inaccurate information based on management decisions. With the advancement of construction technology and the increasing complexity of project structure, the difficulty of cost control is also increasing. Such as the increase of labor over budget, the increase of material costs, and the increase of equipment rental fees; In the project execution stage, sometimes due to the limitation of time limit or manpower, the accuracy of cost accounting work can not be guaranteed, and the actual cost may eventually deviate from the expectation.

2.2.2 Project participants and internal coordination issues

The lack of cooperation among the participants and within the project generally exists in construction projects, which has a huge negative impact on project cost management. The isolated decision-making among various departments cannot bring greater value changes to the overall project benefits. Collaborative work has great potential to reduce costs, and it is also important to deploy and implement collaborative methods, such as schedule management, total quality management, and open accounting.

2.2.3 Knowledge and ability limitations of project cost managers

The lag of cost management concepts makes some traditional cost management concepts and methods unable to meet the needs of modern construction projects, such as insufficient risk estimation and control, and no effective management mechanism has been formed in the continuous cost optimization. The management of the enterprise does not pay enough attention to cost management, and the lack of professional cost management personnel makes the cost.

3. Construction cost management system

3.1.Content and system framework of cost management

3.1.1 Cost management structure

The construction cost management framework usually integrates its management subject, object, content, and relevant specific implementation measures based on project cost management to realize the cost management of engineering projects; It can improve the engineering implementation efficiency and actual profits of enterprises to a certain extent, which plays a very key role in the progress and development of enterprises. A scientific cost management structure requires all the staff involved in the construction project as the management body to put forward their own opinions on the cost management of the project in real-time, establish a full-time feedback mechanism for the whole process of implementation, and realize scientific and effective regulation in the actual production implementation process. The main content of cost management is divided into six modules: cost forecast, cost plan, cost control measures, cost accounting module, cost analysis and calculation module, and final cost assessment.

3.1.2 Cost management object

The object of cost management mainly refers to various costs in enterprises, which can be divided into direct costs and indirect costs. The direct cost is the expenditure spent in the construction process to form the project entity. Such as labor costs, materials costs, and machinery use fees. Indirect cost refers to various expenses incurred in the process of organizing and managing project implementation; The main com-ponent is the remuneration of managers.

3.1.3 Cost management measure

A specific implementation measure can make the cost management in the implementation of engineering projects run scientifically and stably. Management measures systems can be divided into an education system module, a responsibility system module, an index system module, and so on. The operation of a modular management system can ensure that enterprises can obtain higher engineering efficiency and profit results to a great extent, and is an essential part of enterprise cost management.

3.1.4 Cost Management Information System

The cost management information system is a system that uses information technology to manage the cost of an enterprise. Construction Project Cost Management Information System (PCMC) refers to the digital storage, processing, and analysis of all relevant information in the process of cost management to ensure the timeliness, accuracy, and dynamics of cost management. It can help enterprises realize automatic cost management and improve the efficiency of cost management, which is an important means to achieve project cost management. The composition of the construction project cost management framework system is shown in Figure 1.

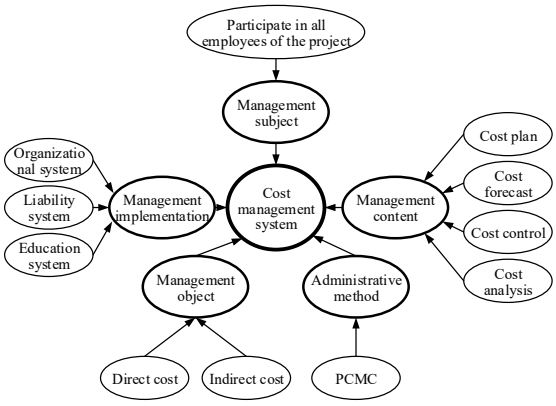

Fig. 1 Composition of construction project cost management framework system

4. Comprehensive application method of BIM technology in cost management

4.1.Five applications of BIM technology in project cost management

As an advanced information technology, BIM expresses structural physics, functions, and characteristics in digital form. The resource-sharing characteristics of BIM promote the possibility of integrating architectural models and project products, which can be used throughout the project life cycle. In different periods of the project, the relevant parties involved in the project use the BIM platform to input, extract and update data, and cooperate to complete the project construction[4]. BIM can be applied to the following five aspects of project management:

1. Check conflicts and save costs. Use BIM visualization 3D technology to reduce collisions and rationalize the scheme. Site construction personnel can clear and intuitive three-dimensional design scheme, which is conducive to high-quality construction.

2. Cost control. BIM3D can be used to simulate construction, and problems can be found in the simulated construction process and corrected in time. At the same time, time parameters are added to the model, and the project progress can be intuitively seen, to reasonably arrange the approach and working time of labor, materials, and machinery, improve the efficiency of project management, and achieve the cost control of the implementation process.

3. Simulated construction and optimized scheme. BIM4D technology is used to increase cost information based on 3D models, optimize the construction process, reduce rework phenomena and errors, and reduce costs.

4. Visual cost accounting. BIM visualization has the advantage of precision and speed for cost accounting. In the traditional mode, the accounting content is numerous, the professional structure is complex, and the work calculation is large. Through the analysis and calculation of the purchasing, warehousing, production, and financial indicators in the model, the results are clear and accurate.

5. Visualization of construction difficulties. For the construction difficulties in the project, such as location conflict, obstruction, design uncertainty, complex construction technology, harsh geographical location, difficult lofting of special-shaped components, etc., the use of BIM 3D visualization can intuitively show the construction site in advance, and greatly improve the construction efficiency and accuracy through the analysis and simulation of construction methods.

4.2.Application method of BIM5D technology in project cost management

BIM5D technology is based on BIM3D technology to introduce schedule management and cost management. The construction period and progress information are attached to the 3D model to form 4D, and the 3D model changes with the change of construction period and progress intuitively on the 4D software model; In addition to the BIM4D model, the cost information becomes the

BIM5D model. In the construction stage, the construction scheme can be simulated and optimized based on BIM5D technology, and the dynamic management of construction costs can be realized. For example, BIM5D can automatically generate a material purchase schedule and fund demand schedule[5]. BIM5D technology can realize the refinement of engineering project cost management and improve the ability of cost management in the construction stage[6]. Figure 2 shows the BIM3D, 4D, and 5D component relationships.

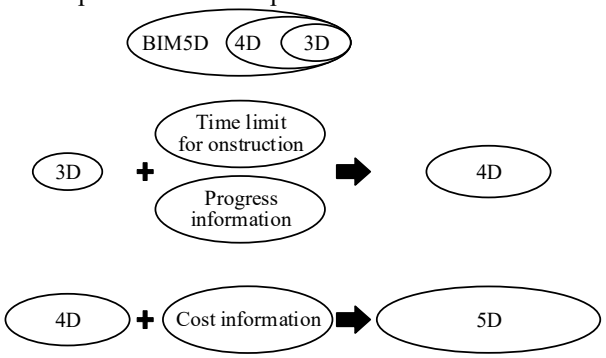

Fig. 2. BIM3D, 4D, and 5D component relationships

4.3.Application method of digital twin in construction project cost management

4.3.1 Digital twin

Digital twins have the same properties as BIM, but the concept of digital twins is broader than BIM in terms of information richness and analytical decision-making capabilities. Jiang et al. made a comparison between digital twins and BIM [7]: The original BIM is more similar to the digital twin, but the digital twin emphasizes the connection with the physical part.

While BIM can be used as a data repository and information source to support the day-to-day operations and maintenance activities of a building, BIM does not provide a complete solution for full life cycle asset management[8]. Compared with digital twins, BIM lacks construction process information and operation and maintenance information[9]. The full life cycle of a digital twin is shown in Figure 3.

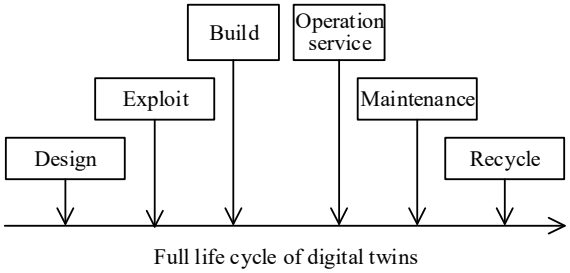

Fig. 3. Flowchart of the full life cycle of digital twins

4.3.2 Digital twins and construction cost management

Digital twins can be applied to other relevant existing projects, relevant environments, and partial completion targets to facilitate construction monitoring and management, including construction progress, quality, safety, workers, machinery, and materials[10]. First of all, the construction phase management is the most complex part of the project management. The advantages of the management based on the digital twin are demonstrated from the perspective of the change of the management mode of the construction phase. Compared with traditional management methods, the management method based on digital twins reduces the harsh requirements on the number of workers and technology through the construction of digital twins and can be managed online or indoors. The uncontrollability of manual management in traditional management mode is changed, and the digitalization of management mode is realized, which further improves the efficiency of cost management. Secondly, based on the superiority of digital twin management in the operation stage. Due to the characteristics of the full life cycle of digital twins, the input work of the construction of digital twins in the early stage will become an important digital asset for engineering projects. Construction and operation management often belong to different management departments, and the traditional management mode has the problem of data wall and information fragmentation, which leads to the difficulty of data transfer. On this basis, the digital realization of the operation and maintenance phase is more convenient. Finally, the establishment of digital twins has an important impact on the construction cost management model. In the traditional management mode, information feedback needs to be transmitted layer by layer. In this process, the problem of communication and understanding leads to information deviation, which affects the final decision. Digital twins provide complete information integration, along with automated forecasting and decision-making, to achieve flat project management. While reducing human intervention, the objective and scientific nature of independent decision-making is realized.

4.4.Integrated application method of BIM5D technology and digital twin

In the real space module of construction personnel, building materials, construction equipment, and geographical environment, the digital twin space of geographic information and BIM-integrated spatial scene is constructed by combining UAV aerial photography with high-precision entity 3D modeling, IOT condition recognition, and BIM5D technology. Through the application of digital twins, remote interaction and management control can be carried out on the components of real space. Figure 4 shows the optimal combination of BIM5D technology and digital twin and the comprehensive application method[11].

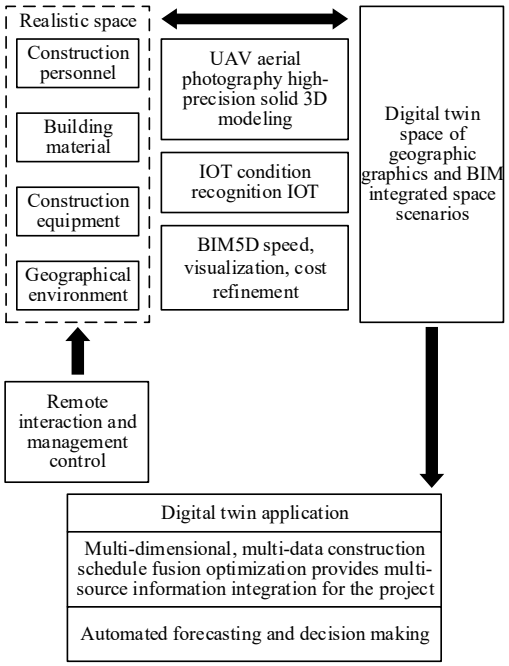

Fig.4. Optimal combination and comprehensive application of BIM5D technology and digital twin

4.5.Practical project application analysis

ZZYH Comprehensive Business Building, a provincial key project located in Zhengzhou, Henan Province, is located in the CBD sub-center of Zhengdong New District, Henan Province, with 4 podium floors, 4 underground floors, and 22 above-ground floors. It is about 100 meters high and has a total construction area of about 90,000 square meters. The structure type is a frame core tube structure. The project investment is about 600 million yuan, and the planned duration is 1013 calendar days. The construction environment of the project is complex and involves many professions and the management scope is wide. In the management process, slow control response, low management intelligence, and other unpredictable conditions appear. This paper selects the comprehensive application of BIM5D technology and digital twin technology to solve these problems effectively[12]. The specific project operation process is as follows:

1. The collection, mapping, integration, and management of basic construction cost management data of actual construction site personnel input, construction equipment work and loss, construction material use, and construction site geographical environment in real space can be realized by IOT condition recognition and interactive modeling of virtual and real information can be realized to provide data basis for intelligent project cost management.

2. Based on BIM technology, the digital twin virtual model of the project is created by adding construction period and progress information and introducing a cost dimension.

3. High-precision acquisition of construction site data by UAV aerial photography is used to conduct three-dimensional entity modeling and realize data mapping of physical entities.

4. The multi-dimensional and multi-data const-ruction schedule integration optimization from three aspects of dynamic resource management, intelligent schedule management, and digital cost control provides multi-source information integration for the project. This paper expounds the application effect of construction cost management under the application of the digital twin concept, realizes the intelligent and scientific management of construction cost, and plays the effect of automatic prediction and decision by remote interaction with real space.

For the economic effect of the project, taking the cost of people, materials, and machinery, which accounted for a large part of the project construction cost, as an example, the cost was reduced by about 1.26 million yuan and the project was completed about 15 days ahead of schedule. The comparison between the budgeted cost and the actual cost of the completed project is shown in Figure 5.

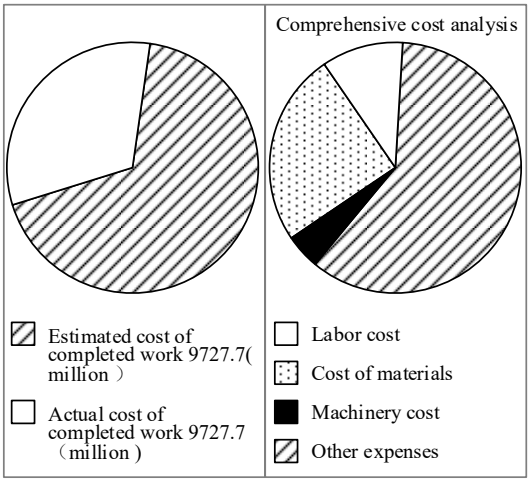

Fig.5. Comparison of estimated cost and actual cost of completed works

5. Conclusions

1. Construction cost management structure can improve the implementation efficiency and actual profits of construction enterprises to a certain extent. Through a large number of literature investigations and analyses, this paper constructs a construction project cost management framework system, which can scientifically and effectively regulate the information management of civil engineering construction cost factors and lays a solid foundation.

2. The comprehensive application approach of BIM technology in project cost management is proposed, and the methods of conflict inspection and cost saving, construction cost control, simulation construction, visual cost accounting, and visualization of construction difficulties are expounded in five aspects, which can significantly improve the level of project management and cost control ability.

3. Introduce BIM5D technology and digital twin, optimize the combination, put forward its comprehensive application method in cost management, and point out that its comprehensive application has a wider application value, can provide superior performance in construction

management, can further improve the efficiency and quality of construction project cost management. On the whole, the comprehensive application of BIM technology plays an important role in solving the problems existing in traditional cost management and improving management efficiency and accuracy.

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