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Practice of Construction Engineering Construction Management Based on 6D-BIM Technology

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Abstract: As an advanced form of Building Information Modeling (BIM), 6D-BIM technology integrates time, cost, and operation and maintenance dimension data based on 3D geometric modeling, forming an integrated management system covering the entire life cycle of buildings. Based on the actual needs of construction engineering and construction management, this paper expounds the technical characteristics of 6D-BIM technology, and deeply analyzes the technical application paths and practical key points from five aspects: integrated construction progress management, dynamic cost control, refined quality management and control, operation and maintenance information delivery, and sustainability analysis. It proposes optimization strategies such as establishing a collaborative workflow, strengthening technical platform construction, cultivating professional talents, and building an entire life cycle collaborative mechanism, to provide practical reference for promoting the digital and intelligent transformation of construction engineering construction management, and help the industry achieve efficient, low-carbon, and high-quality development.

Keywords: 6D-BIM technology; Construction engineering; Construction management; Entire life cycle; Digital transformation; Collaborative mechanism

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1. Introduction

Against the background of the continuously increasing complexity of construction engineering and construction management, 6D-BIM technology provides a systematic solution for construction management with core advantages such as data integration, visual simulation, and full-process collaboration. In recent years, scholars at home and abroad have carried out a lot of research on the application of BIM technology in construction management. Some studies focus on the application of 4D-BIM in construction progress simulation and optimization, realizing dynamic adjustment of construction processes through visual simulation [1]. Other studies explore the practical path of 5D-BIM in cost control and establish a linkage control mechanism between cost and progress. However, existing studies mostly focus on the technical application of a single dimension or partial dimensions, and the systematic application research of 6D-BIM technology covering the entire construction process and operation and maintenance stage still needs to be deepened, especially the lack of practical exploration in data integration standards, cross-departmental collaborative mechanisms, and sustainability analysis [2–4]. Based on this, this paper takes 6D-BIM technology as the research core, systematically analyzes its application scenarios

and implementation key points in construction engineering construction management, puts forward targeted optimization strategies combined with the current technical application status, constructs a new construction management model from the perspective of the entire life cycle, provides theoretical and practical support for improving the efficiency of construction engineering construction management, reducing management costs, and ensuring project quality, and promotes the transformation of the construction industry towards digitalization, intelligence, and greenization.

2. Overview of 6D-BIM technology

6D-BIM technology is a comprehensive information management technology covering the entire life cycle of buildings, which integrates time (4D), cost (5D), and operation and maintenance (6D) dimension information on the basis of 3D-BIM geometric models. As the technical foundation, the 3D dimension constructs a three-dimensional geometric model of building components through parametric modeling, accurately presenting core information such as building structure, pipeline layout, and component dimensions, and providing a carrier for the subsequent integration of data from various dimensions [5]. The 4D dimension introduces time parameters, associates the construction schedule with the 3D model, realizes visual simulation and dynamic adjustment of the construction process, and intuitively presents the schedule arrangement and resource requirements of each construction stage. The 5D dimension integrates cost data, establishes a linkage relationship between engineering quantity, cost, progress, and component information, and supports dynamic cost accounting and deviation analysis. The 6D dimension focuses on the needs of the operation and maintenance stage, and synchronously collects information such as component parameters, equipment performance, and maintenance records during the construction process to provide complete data support for the operation and maintenance of the building after delivery [6].

6D-BIM technology is supported by a database as the core, and realizes effective association and sharing of information from various dimensions through unified data standards, breaking the information barrier between design, construction, supervision, operation, and maintenance parties. Its technical system includes modeling software, data management platforms, visualization tools, collaborative office systems, and other components, which can realize real-time collection, analysis, transmission, and application of construction management data, provide data-driven scientific basis for construction decisions, and promote the transformation of construction management from empirical and decentralized to digital and intensive.

3. Application of 6D-BIM technology in construction engineering and construction management

3.1. Integrated management of construction progress

Integrated management of construction progress and process is the core content of construction engineering construction management, which directly affects project delivery efficiency and resource utilization efficiency. 6D-BIM technology constructs a 4D construction progress simulation model through the deep integration of 3D models and construction schedules, realizing visual planning and dynamic management and control of construction processes [7].

In the early stage of construction, 6D-BIM technology is used to refine and decompose the overall construction schedule, and accurately associate information such as sub-projects, construction processes, and working face allocation with 3D model components. Through the visual simulation function, the component installation sequence, construction machinery configuration, labor deployment, and other situations of each construction stage are intuitively presented, and conflicts and unreasonable points in the construction process are identified in advance [8]. For example, in the pipeline construction of complex buildings, by simulating the sequence of pipeline installation and the requirements of operation space, cross-interference between construction teams of different specialties is avoided, and the connection of construction

processes is optimized. During the construction process, relying on the 6D-BIM data management platform, real-time collection of actual construction progress data is carried out, and a comparative analysis is made with the planned progress. By setting progress early warning thresholds, when the actual progress deviates from the planned progress, the system automatically sends an early warning signal to assist managers in adjusting the construction plan in a timely manner. Combined with 5D cost data, the impact of progress deviations on costs is analyzed to realize the collaborative control of progress and costs.

6D-BIM technology supports collaborative progress management of multiple participants. Design units, construction units, and supervision units share progress information through a unified model platform, and communicate technical issues and progress adjustment needs in the construction process in real time [9]. For example, supervision units can intuitively check whether the construction progress meets the planned requirements through the model and put forward rectification opinions in a timely manner; design units can quickly adjust the design plan through the model according to the actual construction situation, avoiding progress delays caused by design changes. Through full-process and visually integrated progress management, the rationality of the construction process and the accuracy of progress control are effectively improved.

3.2. Dynamic control of project cost and construction cost

Dynamic control of project cost and construction cost is a key link to reducing project costs and improve investment benefits. 6D-BIM technology establishes a dynamic cost control model by integrating multi-dimensional data such as engineering quantity, construction cost, progress, and component information, realizing full-process cost management and control from bidding quotation, construction process to completion settlement [10]. In the bidding stage, engineering quantity information is quickly extracted based on the 6D-BIM model, and an accurate quotation is made by combining market prices, construction plans, and other data. During the construction process, relying on the data integration advantage of 6D-BIM, real-time cost accounting and dynamic adjustment are realized. The cost data of labor, materials, machinery, and other aspects are associated with 3D model components and 4D schedules, and the actual cost of completed engineering quantity is automatically accumulated with the progress of construction. Through comparative analysis with the budget cost, cost deviations are accurately identified, and the causes of deviations are analyzed. For example, when the actual material consumption exceeds the budget, the corresponding components and construction processes are traced through the model to investigate whether the deviation is caused by material waste, design changes, or construction process problems, and targeted control measures are taken in a timely manner. In the completion settlement stage, complete completion settlement documents are quickly generated based on the complete data accumulated during the construction process [11]. The 6D-BIM model completely records the engineering quantity, cost consumption, design changes, and other information during the entire construction process. During settlement, relevant data can be directly extracted from the model for comparative verification with contract terms and bidding quotations, simplifying the settlement process and reducing settlement disputes. Through full-process dynamic cost control, the risk of project cost overrun is effectively reduced, and the project investment benefit is improved.

3.3. Refined management and control of construction quality and process

Refined management and control of construction quality and process is a core means to ensure project quality and improve project quality. 6D-BIM technology realizes full-process and refined management and control of construction quality through functions such as visual simulation, real-time data collection, and process traceability.

In the construction preparation stage, 6D-BIM models are used for technical disclosure and visual display of quality standards. Construction specifications, quality acceptance standards, component installation requirements, and other information are embedded in the 3D model, so that construction personnel can intuitively understand the quality control points and construction process requirements of each component through the model, avoiding quality problems caused by unclear technical disclosure. For example, in reinforced concrete construction, key parameters such as steel bar spacing,

protective layer thickness, and anchorage length are displayed through the model to clarify quality control standards [12]. During the construction process, combined with Internet of Things technology and mobile terminal equipment, real-time collection of construction quality data is carried out and associated with the 6D-BIM model. By deploying sensors, high-definition cameras and other equipment on the construction site, quality data such as component dimension deviations, concrete strength, and pipeline installation accuracy are automatically collected. Construction personnel upload on-site quality inspection results, concealed project acceptance records and other information to the model platform through mobile terminals, realizing real-time entry and sharing of quality data. Using the visualization feature of 6D-BIM technology, complex construction processes are simulated and optimized to predict quality risks in advance. For example, before the construction of complex processes such as steel structure installation and long-span concrete pouring, the model is used to simulate the force conditions during construction and the key points of installation accuracy control, optimize the construction plan, and avoid potential quality hazards caused by unreasonable construction techniques. At the same time, by comparing the actual construction effect with the design standards through the model, construction deviations are found promptly, and deviation correction measures are taken.

3.4. Facility management and operation, and maintenance information delivery

Facility management and operation and maintenance information delivery is one of the core advantages that distinguish 6D-BIM technology from traditional BIM technology, realizing seamless connection of information between the construction stage and the operation and maintenance stage, and providing comprehensive support for the operation and maintenance of the building after delivery [13]. During the construction process, operation and maintenance-related information of building components and equipment is synchronously collected and embedded in the 6D-BIM model. It includes basic information such as component material parameters, service life, maintenance cycle, and maintenance methods, as well as operation and maintenance data such as equipment factory parameters, installation and commissioning records, operating energy consumption data, and fault maintenance records. Through mobile terminal equipment, construction personnel can real-time enter relevant information during equipment installation and commissioning to ensure the completeness and accuracy of operation and maintenance data. In the building completion acceptance stage, complete operation and maintenance information delivery documents are generated based on the 6D-BIM model [14]. The delivery documents not only include traditional completion drawings, equipment specifications, and other data, but also cover an operation and maintenance database containing 3D visualization models. Operation and maintenance units can quickly query relevant information of each component and equipment through the model, intuitively understand the building structure layout, pipeline direction, equipment location, and other situations, and provide convenient tools for operation and maintenance management.

In daily operation and maintenance management, the 6D-BIM model can be used as the core platform for operation and maintenance management. Operation and maintenance personnel locate equipment positions through the model, query equipment operation status and maintenance records, and formulate reasonable maintenance plans. When equipment fails, relevant parameters and maintenance plans of the faulty equipment are quickly found through the model, maintenance resources are dispatched, and the efficiency of fault handling is improved. For example, in the operation and maintenance of central air conditioning systems, real-time monitoring of equipment operating energy consumption, temperature control accuracy and other data through the model, predicting equipment failure risks, and conducting maintenance in advance to reduce equipment failure rates [15].

3.5. Building sustainability and energy consumption analysis

Building sustainability and energy consumption analysis is an important measure to respond to the development concept of green buildings and realize building low-carbonization. 6D-BIM technology realizes sustainability analysis and optimization in the construction stage and operation stage by integrating building energy consumption data, environmental parameters and other information. In the construction stage, 6D-BIM technology is used to optimize the greenization of

construction plans [16]. By simulating links such as earth excavation, material transportation, and construction site layout during the construction process, the impact of construction activities on the surrounding environment is analyzed, and the construction plan is optimized to reduce environmental damage. For example, by simulating earth transportation routes, sensitive environmental areas are avoided to reduce dust pollution during transportation; the layout of temporary facilities on the construction site is optimized to improve land use efficiency and reduce resource waste.

Combined with energy consumption analysis tools, real-time monitoring and optimization of energy consumption during the construction process are carried out. By installing energy consumption monitoring devices on construction machinery and temporary electrical equipment, energy consumption data is collected and uploaded to the 6D-BIM model to analyze the energy consumption differences of different construction plans. For example, compare the energy efficiency of different construction machinery and select energy-saving machinery; optimize the arrangement of construction processes to avoid energy waste caused by idling of mechanical equipment, and reduce energy consumption in the construction stage.

In the integrated process of building design and construction, 6D-BIM technology is used for building energy consumption simulation and optimized design. By integrating information such as building envelope parameters, lighting and ventilation design, and air conditioning system configuration into the model, the energy consumption of the building under different climate conditions is simulated, and high energy consumption links are identified. For example, by adjusting parameters such as external wall thermal insulation materials and window glass types, the thermal insulation performance of the building envelope is optimized; the lighting and ventilation system is reasonably designed to reduce the use time of artificial lighting and air conditioning and reduce energy consumption in the building operation stage. In addition, 6D-BIM technology supports the accounting and control of building carbon emissions. By collecting data such as material consumption and energy consumption during the construction process through the model, combined with carbon emission factors, the carbon emissions during the building construction stage are calculated; in the operation stage, real-time monitoring of building energy consumption and carbon emission data is carried out, compared with carbon emission targets, and emission reduction measures are proposed. For example, reduce carbon emissions during the building operation stage by optimizing the operation mode of air conditioning systems and promoting the use of renewable energy, to realize the goal of building sustainable development.

4. Conclusion

In conclusion, as one of the core technologies for the digital transformation of the construction industry, 6D-BIM technology provides a full-process, visual and intelligent solution for construction engineering and construction management. By integrating multi-dimensional data, it realizes the integrated management of construction progress, cost, quality, operation and maintenance, sustainability and other aspects, and effectively solves the problems of information asymmetry, poor process connection, and unscientific decision-making in the traditional construction management model. In the future, we should increase the R & D and application of 6D-BIM technology, continuously improve technical standards and management models, promote the development of construction management towards digitalization, intelligence, and greenization, and provide strong support for the high-quality development of the construction industry.

Disclosure statement

The author declares no conflict of interest.

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