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Construction Cost Control Strategy of Finished House Based on BIM-5D

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Abstract: Building Information Modeling (BIM) technology can not only achieve project refinement management of the construction process based on a 3D model but also form a BIM-5D model based on the fusion of progress data and cost data to achieve the dynamic control of the whole process of project cost. This paper discusses the application of BIM-5D in the cost control of finished house construction, aiming to provide technical reference for China's finished house project units, so that they can master how to realize the construction of cost control system based on BIM, the monitoring of the key coefficients of the cost, corrective action, to ensure that the project cost deviation is within the controllable range, and to make an effective guarantee for the economic benefits of the project construction.

Keywords: BIM-5D; Finished house project; Cost control system; Cost corrective deviation

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1. Introduction

In recent years, due to economic fluctuations, prices of bulk building materials and equipment in China have become more volatile. This has increased the uncertainty and difficulty of cost control in finished house construction. Additionally, the low degree of industrialization in China's residential decoration sector means that most finished house projects use a menu-type decoration approach, with varying standards, further complicating cost control. Consequently, many housing projects face high input and construction but low output and efficiency. BIM technology, as a widely used digital tool in construction engineering, can establish a 5D cost control model for dynamic cost management in finished housing construction. Therefore, exploring how to achieve cost control of finished house construction based on BIM-5D is essential for the sustainable development of China's architectural and construction enterprises.

2. Connotation of BIM-5D

BIM-5D builds upon traditional three-dimensional spatial information by incorporating the time dimension (4D) and the cost dimension (5D). This integration enables managers to achieve comprehensive and precise project

management. The core of BIM-5D lies in realizing full life cycle cost control and management for the project. On the one hand, the 5D multi-dimensional data model constructed with BIM technology allows the project team to intuitively view and analyze detailed data and information from the design to the construction stages. This transparent information-sharing mechanism ensures scientific decision-making and efficiency, reducing cost wastage due to information asymmetry and miscommunication. On the other hand, BIM-5D integrates time and cost management functions, allowing real-time control of the project schedule and budget, visual display of the construction process, and resource allocation, thereby identifying and addressing cost deviations [1].

3. Finished house construction cost control requirements and the application value of BIM technology

3.1. Finished house construction cost control requirements

Firstly, it is necessary to achieve detailed budgeting for controlling the construction costs of the finished houses. In the early stages of the project, a comprehensive and detailed cost estimation should be carried out, and it should cover the full range of materials, labor, machinery, and other costs to ensure budget accuracy and reasonableness.

Secondly, establishing a systematic control system enables multi-dimensional cost control and monitoring, ensuring continuous oversight of budget implementation and timely identification of cost overruns in specific construction stages. Additionally, effective cost control for finished houses requires digital early warning systems. When a cost overrun occurs, digital technology should be used to trigger alarms and early warnings. This approach addresses the shortcomings of traditional manual management, allowing the project team to identify the root causes of cost deviations and take dynamic corrective measures to prevent issues related to price fluctuations, construction changes, and other budgetary challenges.

3.2. Application value of BIM technology in construction cost control

Firstly, based on the BIM-5D model, budget refinement can be achieved. BIM technology, through its digital and visual 5D model, integrates three-dimensional spatial information and cost data, making the budgeting process more accurate and comprehensive. The project team can use the model to detail and quantify the work involved at each stage and link, resulting in precise and comprehensive accounting. This refined budgeting approach will significantly enhance budget accuracy and provide solid data support for subsequent cost control.

Secondly, BIM technology facilitates systematic multi-dimensional cost management. BIM software offers an integrated platform covering design, construction, procurement, operation, and other project life cycle costs. This platform centralizes, manages, and analyzes all project-related cost information, allowing the project team to fully understand and control cost changes across different segments, ensuring that construction stays within budget. Additionally, this systematic approach covers not only direct costs like materials, labor, and machinery but also indirect costs such as management and operating expenses, supporting investment decisions, and business management.

Finally, BIM enables dynamic cost monitoring and early warning for the project, demonstrating strong dynamic management and real-time alert capabilities. During construction, the BIM model records and updates cost data in real-time, allowing the project management team to monitor and analyze cost deviations and potential risks promptly. The BIM system also provides early warning notifications and corrective suggestions, helping the team take effective measures to prevent cost overruns and schedule delays through digital means [2].

4. Construction cost control strategy based on BIM-5D in finished house project

4.1. Background of finished house project

Changchun Surgical – Golden Mansion is located at the interchange of Longhu Road and Beiwan East Street in Changchun City, Jilin Province. This project features small high-rise and high-rise slab floor finished houses with decorative delivery. The Golden Mansion project covers an area of 48,091 m^2, with a construction area of 131,580 m^2. It is adjacent to the large-scale commercial center Beihu Wuyue Plaza and near the Light Rail Line 8. The development includes 30% internal greening, complete supporting facilities, and a 24-hour security system. The buildings adhere to modern aesthetic concepts, blending traditional and contemporary elements to create a comfortable and safe living environment for residents.

4.2. Establishment of 5D construction cost control model based on BIM

In Vanke – Golden Mansion finished house project, under the construction cost control strategy based on the BIM-5D model begins with establishing a 3D model from Computer-Aided Design (CAD) drawings. This model is then enhanced by adding a time dimension and a cost dimension, using Revit software to build the complete BIM-5D model, as shown in **Figure 1**.

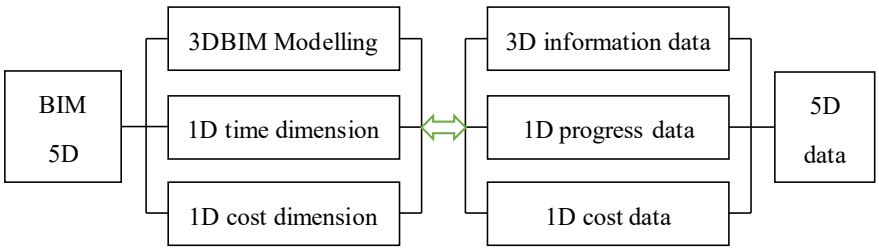

Figure 1. Schematic diagram of BIM-5D model

In the first step, the BIM-3D model is created based on CAD drawings, using Revit software to convert 2D design drawings into 3D models. The model must include all professional information, such as architecture, structure, and electromechanical details, to form a comprehensive 3D model.

In the second step, schedule information is added to create the BIM-4D model. This involves using the Work Breakdown Structure (WBS) to detail project tasks, with each sub-task having a clear time plan [3]. Microsoft Project is used to develop the schedule, and the time data is exported and imported into Revit, linking model elements with time nodes to dynamically reflect construction progress.

In the third step, cost information is integrated into the BIM-4D model. During the operation stage, cost accounting is performed for each WBS sub-task using Navisworks cost estimation software, detailing each cost. This cost data is then imported into Revit and linked with the schedule information, so each model element has actual cost attributes, achieving multi-dimensional integration of time and cost.

In the above BIM-5D model establishment, task decomposition and data integration are the keys to establishing the BIM-5D model. In the operation phase, the project should be decomposed into multiple sub-tasks using WBS, covering the whole construction life cycle from foundation works to house decoration. The actual operation stage requires highly accurate progress information and cost information.

4.3. Establishment of 5D construction cost control system based on BIM

Based on establishing the BIM-5D model, the 5D construction cost control system is constructed, aiming at realizing the comprehensive management and monitoring of the project budget and actual cost data, which covers the four main management functions of the progress plan, budget cost, actual progress and actual cost [4].

The first step involves designing the schedule module. Using the BIM-5D model, the project's building and foundation works are refined to the work package level in phases using WBS, ensuring each work package includes a specific time plan. These plans are then associated with the corresponding components in the BIM model. In Revit, the time plan for each process is imported into the BIM-4D model, achieving dynamic visualization and management of the schedule.

The budget cost module, responsible for managing estimated project costs, integrates quantity data, standard quotas, and market prices in the BIM-5D model to generate the total budget for each WBS task [5]. Navisworks automatically generates a detailed list of material, manpower, and equipment costs which is correlated with each structural part in the 5D model, assigning budget cost attributes to each model component. For the actual schedule module, a detailed schedule is created in Microsoft Project, and the 5D model data is updated based on schedule adjustments and actual data [6]. For actual cost management, detailed records of completed work estimates, actual material, and labor costs are recorded and compared with budget data in real time. By regularly updating the 5D model with actual cost data, the construction unit allows to accurately monitor the actual cost expenditure at each stage, resulting in a "Completed Actual Cost Summary Table."

In the second step, based on the design of these basic functions, the BIM system performs cost deviation and performance analysis using cross-calculation methods with the input data. It regularly calculates completed actual costs, completed budget costs, and planned work costs. This analysis provides cost performance and schedule performance indicators, helping the project team quickly identify cost deviations and their metrics. When deviations are detected, the system triggers a cost early warning mechanism, generates a deviation report, and prompts the project team to analyze and address the deviations [7].

4.4. Confirmation of cost monitoring parameters

After completing the construction of the 5D cost monitoring system, the project construction stage cost monitoring parameters were confirmed. For the Vanke-Golden Mansion finished house project, the project team establishes the monitoring parameters as Budgeted Cost of Completed Work (BCWP), Budgeted Cost of Planned Work (BCWS), and Actual Cost of Completed Work (ACWP) [8]. BCWP represents the amount of work completed (WP) multiplied by the Budgeted Unit Price (BC), reflecting the final cost of completed work for a specific period. BCWS is the amount of work planned (WS) multiplied by the BC, indicating the future cost of planned work. ACWP is the amount of work performed (WS) multiplied by BC, showing the actual cost of work performed up to a certain point in time. It is calculated as the amount of work completed (WP) multiplied by the Actual Unit Price (AC) to determine the actual cost incurred [9]. The Earned Value Method is used to calculate four basic parameters: Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI), and Schedule Performance Index (SPI):

$$CV = BCWP - ACWP$$

$$SV = BCWP - BCWS$$

$$CPI = \frac{BCWP}{ACWP}$$

$$SPI = \frac{BCWP}{BCWS}$$

4.5. Cost monitoring and deviation warning

The above CV, SV, CPI, and SPI are monitored in real-time, and the BIM system automatically carries out deviation analysis and monitoring based on the actual situation calculated from the adopted numbers. Taking the CPI value as an example, during the monitoring of CPI parameters, the CPI warning value is set to five levels, i.e., the deviation level is very high, the deviation level is high, the deviation level is medium, the deviation level is low, and the deviation level is very low. The corresponding CPI values are 0 to 0.6, 0.6 to 0.75, 0.75 to 0.78, 0.85 to 0.95, and above 0.95, respectively. The deviation warning values specifically for CPI thresholds are shown in **Table 1**.

Table 1. Cost bias warning for CPI parameters

CPI value	Deviation level	Hierarchy	Early warning signal
0–0.6	Very high deviation level	I	Red signal
0.6–0.75	High deviation level	II	Orange signal
0.75–0.85	Medium deviation level	III	Yellow signal
0.85–0.95	Low deviation level	IV	Blue signal
＞ 0.95	Very low deviation	V	Green signal

4.6. Cost Correction

For different types of cost deviation, the Vanke - Golden Mansion finished house project team, combined with different basic parameter relationships, formed different types of deviation and formulated targeted solutions [10]. Specific reference can be made to **Table 2**.

Table 2. Cost deviation parameter relationships and solutions for Vanke - Golden Mansion finished house

Parameter relationships	Classification of deviations	Evaluation indicators	Solutions
	Inputs ahead of schedule, fast and efficient	$SV>0, CV>0$ $CPI>1, SPI>1$	Downsize crews, slow down construction tempo
	Faster and more efficient but lagging behind in inputs	$SV>0, CV>0$ $SPI>1, CPI>1$	Adjust for deviations, or maintain the status quo if deviations are small
	Highly efficient, but behind schedule and behind inputs	$SV<0, CV>0$ $SPI<1, CPI>1$	Increase crew inputs
$BCWS>ACWP>BCWP$	Behind schedule, behind inputs and inefficient	$SV<0, CV<0$ $SPI<1, CPI<1$	Increase crew inputs to improve efficiency
$ACWP>BCWS>BCWP$	Behind schedule, inefficient but ahead of inputs	$SV<0, CV<0$ $SPI<1, CPI<1$	Replace highly efficient machinery and crews
$ACWP>BCWP>BCWS$	Inputs ahead of schedule but inefficient	$SV>0, CV<0$ $SPI>1, CPI<1$	Reduce crew inputs, promote resource balance

5. Conclusion

As analyzed above, this paper researches the application of BIM-5D in the construction cost control of the finished house project, takes Vanke-Golden Mansion project as an example, and explores the establishment process of BIM-5D model, along with the establishment and application strategy of the cost control system based on 5D model. The construction team of the finished house project can learn from this paper to carry out the establishment of the cost control program, give full play to the advantages of BIM technology, effectively

control the cost parameter deviation during the project construction process, ensure that the cost deviation is always within the acceptable range of the project, and achieve dynamic cost management based on the perfect model to provide technical guarantee for the implementation of the project construction goals.

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Disclosure statement

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