Applied Research on BIM-Based Project Cost Control Methods (Postprint)

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Abstract

Current engineering cost estimation is generally based on 2D drawings provided by designers, requiring model reconstruction, calculation, and aggregation to obtain final data. Cost engineers typically become involved during the construction drawing phase, while specific engineering design decisions often overlook comparative economic rationality analyses. Establishing integration patterns between BIM models and commonly used cost estimation software would enable cost control factors to participate in decision-making during design discussions, eliminate the modeling process inherent in conventional engineering cost calculations, improve work efficiency, and simultaneously exploit the rich information embedded within BIM models.

Full Text

Preamble

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Research on Engineering Cost Control Methods Based on BIM Technology

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Abstract: Current project budgeting typically relies on two-dimensional drawings provided by designers, requiring model reconstruction to calculate and summarize final data. Cost engineers generally become involved only during the construction drawing phase, often neglecting economic rationality comparisons in specific engineering design decisions. This study seeks to identify effective integration patterns between BIM models and commonly used cost estimation software, enabling cost control factors to participate in decision-making during design discussions, eliminating the modeling workflow in conventional cost calculations, improving work efficiency, and simultaneously extracting the rich information embedded in BIM models.

Keywords: Design-Quantity Surveying Model; Modeling Standards; Cost Control

1. BIM Design Quantity Surveying and Project Environment

1.1 Quantity Surveying Technology Overview

As market demands for project complexity continue to increase, project scales are growing larger, and irregular and heterogeneous structures are becoming more common. These developments have made traditional two-dimensional drawings inadequate for clearly and completely expressing design information. Precisely because of these limitations in 2D drawings, project schedules and costs face significant challenges, making product quality control difficult. Meanwhile, clients are demanding higher standards—not only ensuring quality and economy but also requiring energy efficiency, green building features, and sustainability. BIM technology has emerged in response to these strong market demands.

In actual engineering practice, cost personnel typically become involved during the construction drawing phase, and specific engineering design decisions often overlook economic rationality comparisons. BIM-based three-dimensional models can automatically generate material lists that update in real-time with design changes. Therefore, fully utilizing these material lists to investigate their correspondence with traditional bill of quantities, identifying problems and research conclusions in BIM-based cost control, enables cost factors to participate in decision-making during design discussions. Simultaneously, seeking integration patterns between BIM models and common cost software can eliminate the modeling workflow in conventional cost calculations, improve work efficiency, and extract the rich information in BIM models to provide more effective services for other project participants.

Through applied research on actual projects, this study uses BIM models to calculate quantities for different design schemes, identifies the correspondence between BIM model quantities and results from common quantity surveying software, leverages BIM models for quantity calculation in professional surveying software to eliminate the modeling process, compares process data, and investigates import methods between BIM models and common quantity surveying software. Although numerous difficulties were encountered in this process, increased attention to these issues will lead to their gradual resolution.

1.2 Work Platform Overview

BIM Technology: BIM is an engineering data model based on three-dimensional digital technology that integrates various project-related information, providing a detailed digital expression of the engineering project. It provides coordinated, internally consistent, and computable information for the establishment and use of construction projects during design and construction.

Autodesk Revit: As one of the BIM 3D design software platforms, Revit has become very mature internationally and has developed rapidly in China in recent years, though its localization still requires further improvement. The development of foreign software in China inevitably encounters localization issues. However, as the preferred platform for design modeling, Revit can currently resolve most issues during the design process across various disciplines, with additional requirements better achieved through third-party software support.

Glodon GCL Software: The Glodon Civil Construction Quantity Surveying Software GCL adheres to principles of professionalism, accuracy, simplicity, and efficiency, achieving significant breakthroughs in both business and technical aspects. It enables modeling and calculation of inclined arch components, one-click import of 3D design models, substantially improved recognition rates for 2D CAD drawings, and efficient calculation of single components and elements. The software can quickly and accurately process complex models, reuse multiple design models for efficient modeling, and flexibly calculate summaries, comprehensively improving modeling and calculation efficiency to enable users to quickly obtain required quantities. GCL serves as the civil construction quantity surveying platform for modeling and data export, with Glodon pricing software as the supporting pricing tool.

Currently, quantity calculation work generally accounts for 50%-70% of the entire budgeting process, with most of this time spent on modeling.

1.3 Project Environment Introduction and Configuration

For different projects, corresponding project environments must be configured on both the design work platform and the quantity surveying/pricing platforms. On the design work platform, different building forms directly determine the project templates used on the Revit platform, while project scale also imposes different requirements on environmental settings. This design environment demands high requirements for subsequent reporting and unified functions, all of which are addressed at the work platform level. On the quantity surveying platform, calculation methods vary according to different projects, with different requirements for civil construction, fine decoration, and MEP environments, while different work tasks are assigned to professionals in each discipline. Both of these constitute the project environment at the management level, forming the complete project environment together. Project environment configuration is a prerequisite for smooth project execution.

2. Comparison Between Traditional Cost Workflow and BIM Technology Application

2.1 Conventional Design Estimation Process and Existing Problems

Under the traditional whole-process cost management model, architectural design is generally divided into three stages: schematic design, preliminary design, and construction drawing design. In these three stages, designers understand client requirements based on descriptions, obtain necessary data, and then proceed with more detailed design. The three stages of scheme design, evaluation, and final selection are all completed based on whole-process cost control, using whether the scheme estimate exceeds the budget estimate and whether the budget exceeds the estimate as basic design criteria. The entire design process emphasizes construction cost control, generally ignoring or not comprehensively considering operation and maintenance phase costs.

In the traditional whole-process cost management model, cost management runs from the decision-making stage to the completion and delivery stage, implementing reasonable determination and control of project costs. The design stage estimate serves as the maximum limit for project cost control, with subsequent construction drawing budgets and final settlement not exceeding the design estimate. The whole-process cost management model focuses on the decision-making and design stages, with the design stage being particularly important for cost control, influencing cost by 75%-95%. If BIM technology is adopted during the design stage for complete spatial modeling of building structures, enabling detailed 3D design of nodes and generating 2D drawings from 3D models, it can not only improve design efficiency but also provide model information needed for later stages. Meanwhile, large-scale complex projects involve massive component data requiring more participants for collaborative work and centralized quality control—a need that aligns perfectly with BIM technology' s advantages. Precisely because BIM technology can play such a significant role in design estimation, adopting BIM technology for rapid quantity surveying during the preliminary design stage is imperative.

2.2 BIM Application in Design Estimation Work

It is well known that Revit is a relatively popular software in the design stage. A complete Revit model is a full-discipline BIM model containing the entire building, structure, and MEP 3D modeling, detailed information of various components, and information on wall materials, volume sizes, and other details. It can directly export material lists such as concrete volumes and wall areas, enabling project cost estimation based on this data. However, this approach also encounters problems in actual practice, as differences in calculation methods and model processing between 3D and 2D create new obstacles to rapid cost calculation and application.

2.3 BIM Technology Survey Conclusions in the Cost Industry

If models can be transferred from the design stage source to the transaction and construction stages, the following effects can be achieved: (1) Significantly improve the work efficiency of cost personnel, eliminating the need to remodel during the quantity surveying stage and reducing workload by over 50%; (2) Guide and implement bidding, pre-settlement, and settlement, improving work efficiency, with all stages based on the same model for quantity calculation, enabling early start of quantity surveying and avoiding disputes; (3) Improve the quality of subsequent work.

Simultaneously, our research found that the main reasons preventing model data from being transferred downstream include: (1) Cost models generated during construction are not included in design models; (2) Components represented with simplified design expressions are not included in cost BIM models; (3) Differences in practices between design BIM model software and cost software; (4) Differences in calculation methods between design BIM model software and cost software.

3. Project Case Testing and Practice Results

3.1 Project Overview

The project is a secondary school campus jointly constructed by a university-affiliated middle school and the education commission. The main construction content includes high school teaching and laboratory buildings, junior high school teaching and laboratory buildings, gymnasium, art building, cafeteria, teacher apartments, student dormitories, covered corridors, communication rooms, guard rooms, spectator stands, etc., along with implementation of major municipal pipelines, outdoor pipelines within the red line, roads and squares, walls, gates, greening, lighting, and other works. The practice content focuses on the teacher dormitory building with a construction area of 8,800 m², one underground floor and six above-ground floors, a building height of 18 m, and a frame structure.

3.2 BIM Application and Results Before Design Change

This project is a real production project involving BIM application during the design stage. The model has been completed according to the quantity surveying test requirements and objectives. Before model construction, BIM model component naming standards were planned in accordance with our institute' s BIM modeling requirements and application points in the civil quantity surveying workflow. Component naming in this project follows a five-segment system, such as the concrete column model: CABR.F3.KZ7.700X700-C30. Due to the unique characteristics of numerous components in architecture and structure disciplines, the naming principle follows the above format but is not rigidly limited to five segments. The general principle is: unit information–floor information

—component type information—specification information—strength information, etc.

After exporting through GFC, the file size has been reduced from 27.16 MB in the design data format to 2.37 MB, achieving 90% lightweighting. It is evident that after the BIM model is exported through GFC, intelligent matching and automatic processing have been performed on the model according to quantity surveying rules, making the model more suitable for quantity surveying requirements. During the import and export process, extremely limited manual modifications and adjustments are required, not exceeding the model inspection and adjustment workload after traditional mode quantity surveying modeling. After importing the BIM model into the Glodon civil construction quantity surveying software, the national standard bill of quantities calculation is performed using the civil construction quantity surveying software, as shown in [Figure 5: see original paper].

Through comparison of the above data, it was found that the quantity data for walls, beams, slabs, and columns exported through BIM technology is smaller than that from traditional quantity surveying methods. Analysis reveals that traditional quantity surveying methods consider formwork loss and other engineering quantities for this portion of work, resulting in data differences. For example, in the wall engineering category, the entry for "wall engineering brick walls, block walls, and brick column self-insulating block external walls with 200mm thickness" shows 3,584.7 m^2 in the former method versus 4,084.16 m^2 in the latter.

3.3 BIM Application and Results After Design Change

Merely using normal design process data cannot meet the research objectives of this cost control study. Therefore, when changes occurred during the project, we conducted statistical analysis of engineering quantities exported from the BIM design process and compared them with corresponding traditional quantity surveying processes and results.

Change Description: Due to client requirements, the function of some rooms changed, building partition wall positions were adjusted, floor height changed from 2.9 m to 3.0 m, and structural loads changed accordingly. After calculation, the height of some beams changed correspondingly. On the first floor at axis C-D/1-2, the room function changed from storage to dormitory. Beam height within the -0.1 m range increased by 100 mm, and corresponding partition walls were adjusted accordingly.

The Revit design room function change is shown in [Figure 7: see original paper]-[Figure 8: see original paper]. The exported design room function change in the quantity surveying software is shown in [Figure 9: see original paper]-[Figure 10: see original paper].

After importing the BIM model into the Glodon civil construction quantity surveying software, the national standard bill of quantities calculation is performed using the civil construction quantity surveying software, as shown in [Figure 11: see original paper].

Through the traditional quantity surveying workflow (drawings → quantity surveying), the completed quantity surveying results are shown in [Figure 12: see original paper].

It was found that the relative proportion of changes remained consistent with that before the change, indicating stable results. Let us examine the data comparison during the change process. Human resource data for change quantity surveying using traditional methods is shown in , while human resource data for change quantity surveying after importing the BIM design into the quantity surveying model is shown in .

Through comparison of the two sets of data, the time consumption in human resources is mainly manifested in communication between designers and budget officers, with a very significant gap. After determining the change content, excluding the time for remodeling, the remaining workload for quantity surveying and pricing basically remains unchanged.

3.4 Project Practice Summary

Practice has proven that using one BIM model for multiple purposes to achieve interoperability between design models and quantity surveying models is technically completely feasible. It also verifies that BIM can provide faster feedback on engineering quantities during the design process, which is crucial for both clients and designers. However, in specific practice, model interoperability imposes high requirements on model standardization, necessitating the development of a set of methodological rules through trial and exploration—rules that require more project practice for verification and refinement.

4. Key Points of BIM Technology for Project Cost Control

4.1 Design Drawing Modeling Requirements

Through Revit' s built-in schedule function, model components can be filtered, summarized, and expressed according to various attribute information. However, the components in the model entirely depend on modeling methods and level of detail. Therefore, the quantities listed in the schedule are "net quantities" —the net geometric dimensions of model components—which still differ from our traditional bill of quantities. Consequently, establishing design modeling rules is a critical component. Only by continuously improving modeling rules can we achieve smooth transfer of design models to deeper applications such as quantity surveying models, thereby increasing the added value of models.

4.2 Design Process Standardization

For BIM technology to be vigorously developed in the design industry, the primary issue to address is design process standardization, including efficiency issues. Efficiency depends to some extent on whether BIM software can quickly achieve rapid modeling operations through standardized design. If batch creation and editing of models can be achieved quickly while accurately and rapidly assigning non-geometric information to models, and because design standardization has not yet been implemented, coupled with current software' s inability to effectively achieve efficient modeling, these issues require resolution through improvements in design workflows and the software itself.

4.3 Component Library Standardization

The component library is the most basic unit in the 3D design process. A comprehensive component library is crucial for improving work efficiency. The system' s built-in families far from meet design requirements. Only with a complete component library can work efficiency be greatly improved. Building a comprehensive component library is a gradual process. As design process standardization and drawing standardization progress and project accumulation increases, the component library becomes increasingly complete, with previous components continuously improved during use.

4.4 Reinforcement Requirements

Currently, Revit can basically accurately calculate concrete usage, but there are certain problems in calculating reinforcement usage. Given that current software functions for drawing component reinforcement are not intelligent enough, reinforcement drawing basically requires designers to adjust according to code requirements—a task with extremely huge workload. If various structural reinforcement codes compliant with domestic design could be embedded in the software, the anchorage length and hook requirements of reinforcement could be directly considered during the drawing process, thereby incorporating reinforcement quantity surveying applications into the design process to make our cost control more precise and practical.

5. Conclusion

BIM technology represents another transformation in the design industry, and its role throughout the entire lifecycle of design is self-evident. BIM technology runs through the entire lifecycle of design, construction, and operation and maintenance, posing challenges to structural design while also providing an alternative work model. Although various BIM software still has certain defects, such as imperfect data exchange between 3D modeling software and calculation software, as software gradually improves and localization advances, 3D design-to-cost technology will become as complete and mature as traditional design-to-cost technology. Obstacles to applying BIM technology in various stages will certainly be overcome one by one, and BIM technology will undoubtedly demonstrate its strengths in the design-to-cost field in the future, providing powerful support with its advantages becoming clearly evident in the coming years.

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Note: Figure translations are in progress. See original paper for figures.