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

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Abstract

Current engineering cost estimation generally relies on 2D drawings provided by designers, requiring model reconstruction and computational aggregation to derive final data. Cost engineering personnel typically become involved at the construction drawing stage, while specific engineering design decisions often overlook comparative analyses of economic rationality. The pursuit of integration modes between BIM models and commonly used cost estimation software aims to incorporate cost control factors into decision-making during design scheme discussions, eliminate the modeling workflow in conventional engineering cost calculations, improve work efficiency, and simultaneously leverage the rich information of BIM models.

Full Text

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, while specific engineering design decisions often neglect comparative economic rationality analysis. This study seeks to identify effective integration methods 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 Model; Modeling Standards; Cost Control

1. BIM Design Quantity Calculation and Project Environment

1.1 Quantity Calculation Technology Overview In recent years, market demands for project complexity have continuously increased, with project scales growing larger and more irregular and heterogeneous structures appearing frequently. 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, hindering effective quality control. Simultaneously, end-users demand 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, while 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, by fully utilizing these material lists and studying their correspondence with traditional bill of quantities, we can identify issues and research conclusions regarding BIM-based cost control. This enables cost control factors to participate in decision-making during design discussions, while also seeking integration methods between BIM models and commonly used cost software to eliminate the modeling workflow in conventional cost calculations, improve work efficiency, and extract the rich information from BIM models to provide more effective service information for other project participants.

Through applied research on actual projects, we used BIM models to calculate quantities for different design schemes, identified the correspondence between BIM model quantities and results from conventional quantity calculation software, utilized BIM models for quantity calculation in professional calculation software to eliminate the modeling process, compared process data, and studied import methods between BIM models and conventional quantity calculation software. However, numerous difficulties were encountered in this process, which will gradually be resolved as attention to these issues increases.

1.2 Work Platform Overview BIM is an engineering data model based on three-dimensional digital technology that integrates various types of information related to construction projects. It represents a detailed digital expression of all relevant project information, providing 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 three-dimensional design software platforms, has become very mature abroad and has developed rapidly in China in recent years, although its localization still requires further improvement. The development of foreign software in China inevitably encounters localization issues, which is unavoidable. However, Revit serves as the preferred platform for design modeling and can currently resolve most problems encountered by various disciplines during the design process, with additional requirements better achieved through support from third-party software.

Guanglianda' s civil engineering calculation software GCL adheres to principles of professionalism, accuracy, simplicity, and efficiency in the cost industry, achieving significant breakthroughs in both business and technical aspects. It enables modeling and calculation of sloped and arched components, one-click import of three-dimensional design models, substantially improved recognition rates for two-dimensional CAD drawings, and efficient calculation of individual components and elements. The software can quickly and accurately process complex models, reuse various design models for efficient modeling, and flexibly perform calculation summaries, comprehensively improving modeling and calculation efficiency and enabling users to quickly obtain required quantities. GCL serves as the civil engineering calculation platform for modeling and data export, with Guanglianda software selected as the supporting pricing software.

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 Overview and Configuration For different projects, corresponding project environments must be configured on both the design work platform and the calculation/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 consistency in reporting requirements and unified functionality at the work platform level. On the calculation platform, calculation methods vary according to project differences, with different requirements for civil construction, fine decoration, and MEP environment settings, while assigning different work tasks to professionals in each discipline. Both of these constitute project environments at the management level, together forming the complete project environment. Project environment configuration is a prerequisite for smooth project execution.

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2. Comparison of 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. During these three stages, designers understand requirements and obtain necessary data from the client before proceeding with more detailed design. Scheme design, evaluation, and final selection are all completed based on whole-process cost control, using whether the scheme estimate exceeds the investment 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 through to project completion and delivery, implementing reasonable determination and control of project costs. The design estimate from the design phase serves as the maximum limit for project cost control, with subsequent construction drawing budgets and final settlement not allowed to exceed the design estimate. The whole-process cost management model focuses on the decision-making and design phases, with the design phase being particularly crucial for cost control, influencing 75%-95% of total cost. If BIM technology can be adopted during the design phase to conduct complete spatial modeling of building structures, enable three-dimensional design of detailed nodes, and generate two-dimensional drawings from 3D models, it can not only improve design efficiency but also provide model information needed for subsequent phases. Meanwhile, large-scale complex projects involve vast amounts of component data requiring multi-party collaboration for 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, rapid quantity calculation using BIM technology during the preliminary design phase is imperative.

2.2 BIM Application in Design Estimation Work It is well known that Revit is a relatively popular software in the design phase within the industry. A complete Revit model represents a full-discipline BIM model containing the entire building, structure, and MEP 3D models, detailed information of various components, and information on wall materials, volume sizes, and other detailed nodes. 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 practical work, as three-dimensional and two-dimensional calculation methods and model processing methods differ, creating new obstacles to rapid cost calculation and application.

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

Through research, we found that the main reasons preventing model data from being transferred downstream include: (1) Cost models generated during construction are not present in design models; (2) Components represented with simplified design notation are not present 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.

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3. Project Case Testing and Practical 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, a gymnasium, an arts building, a cafeteria, teacher apartments, student dormitories, a covered corridor, a guard room, a gatehouse, and spectator stands. Synchronized implementation includes major municipal pipelines, outdoor pipelines within the red line, roads and plazas, walls, gates, landscaping, lighting, and other works. The practice content focuses on the teacher dormitory building with a construction area of 8,800 m^2, 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 phase. The model was completed according to the requirements and objectives of this quantity calculation test. 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 engineering calculation 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 both architecture and structure disciplines, the naming principle follows the above format but is not rigidly limited to the five-segment system. The general principle includes unit information, floor information, component type information, specification information, and strength information.

The Revit design architecture and structure model was exported to the Guanglianda calculation software through the GFC format. After export, the file size was reduced from 27.16 MB in the design data format to 2.37 MB, achieving 90% lightweighting. This demonstrates that after BIM models are exported through GFC, intelligent matching and automatic processing are performed according to calculation rules, making the models more suitable for quantity calculation requirements. During the import/export process, extremely limited manual modifications and adjustments are required, not exceeding the model detection and adjustment workload after traditional mode quantity calculation modeling. After importing the BIM model into Guanglianda civil engineering calculation software, the national standard bill of quantities calculation was performed using the civil engineering calculation software, as shown in [Figure 5: see original paper].

Through comparison with the traditional quantity calculation process, the data revealed that quantities for walls, beams, slabs, and columns exported through BIM technology were smaller than those from traditional calculation methods. Analysis indicates that traditional quantity calculation methods consider formwork loss and other engineering quantities for this portion of work, resulting in data differences. For example, in the wall engineering item "brick walls, block walls, and brick column self-insulating block external walls with 200mm thickness," the former is 3,584.7 m^2 while the latter is 4,084.16 m^2.

3.3 BIM Application and Results After Design Change Data from the normal design process alone cannot satisfy the research objectives for cost control. Therefore, when changes occurred during the project, we exported and statistically analyzed engineering quantities from the BIM design process and compared them with corresponding traditional quantity calculation 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 accordingly. On the first floor at axis C-D/1-2, the room function changed from warehouse to dormitory. Beam height within the -0.1 m range increased by 100 mm, and corresponding partition walls were adjusted.

The Revit design room function change is shown in [Figure 7: see original paper]-[Figure 8: see original paper]. After exporting to the calculation software, the design room function change is shown in [Figure 9: see original paper]-[Figure 10: see original paper]. After importing the BIM model into Guanglianda civil engineering calculation software, the national standard bill of quantities calculation was performed.

Through the traditional quantity calculation workflow (drawings → quantity calculation), the results are shown in [Figure 12: see original paper]. The comparison revealed that the relative proportion of change quantities remained unchanged, consistent with pre-change data, indicating stable results. Examining the process data comparison, human resource data for change quantity calculation using traditional methods is shown in , while human resource data for change quantity calculation after importing the BIM design model is shown in .

Comparing the two datasets, the time consumption difference is primarily manifested in communication between designers and estimators, with a significant gap. After determining the change content, excluding the time for remodeling, the remaining workload for quantity calculation and pricing remains essentially unchanged.

3.4 Project Practice Summary Practice has proven that using a single BIM model for multiple purposes and achieving interoperability between design models and quantity calculation models is technically feasible. It also verifies that engineering quantities can be fed back more quickly during the design process, which is crucial for both clients and designers. However, model interoperability imposes high requirements on model standardization, requiring the development of a set of methodological rules through trial and exploration—rules that need validation and refinement through more project practices.

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4. Key Aspects 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, components in the model entirely depend on modeling methods and level of detail. Therefore, the quantities listed in schedules represent "net quantities" —the net geometric dimensions of model components—which still differ from traditional bills of quantities. Consequently, establishing design modeling rules is a critical component. Only by continuously improving modeling rules can smooth transfer from design models to quantity calculation models and other deep applications be achieved, adding value to the 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 concerns. Efficiency depends to some extent on whether BIM software can quickly achieve modeling operations through standardized design. If rapid batch creation and editing of models can be achieved while accurately and quickly assigning non-geometric information to models, the technology can be more widely adopted. Since standardization has not yet been implemented in design, and current software itself cannot effectively achieve efficient modeling, these issues require resolution through improvements in both design workflows and software capabilities.

4.3 Component Library Standardization The component library is the most fundamental unit in the three-dimensional design process. A comprehensive component library is crucial for improving work efficiency. The families provided by the system itself far from meet design requirements. Only with a complete component library can work efficiency be greatly improved. Developing a component library is a gradual process—as design processes become standardized, drawings become standardized, and project accumulation increases, the component library will become increasingly comprehensive, with existing components continuously improved through usage.

4.4 Reinforcement Requirements Currently, Revit can basically accurately calculate concrete quantities, but faces certain issues in steel reinforcement quantity statistics. Given that current software functions for component reinforcement drawing are not sufficiently intelligent, reinforcement drawing essentially requires designers to adjust according to code requirements—a task with enormous workload. If various domestic structural reinforcement codes could be embedded in the software, reinforcement anchorage lengths and hook requirements could be directly considered during the drawing process, enabling reinforcement quantity calculation applications during the design phase and making cost control more accurate and practical.

Conclusion

BIM technology represents another transformation in the design industry, with its role throughout the entire lifecycle being self-evident. BIM technology runs through the entire lifecycle of design, construction, and operation and maintenance, posing challenges to structural design while 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—these will gradually be resolved as software improves and localization advances. It is believed that 3D design-to-cost technology will become as refined and mature as traditional design-to-cost technology, and obstacles to BIM technology application in various stages will be overcome one by one. In the future, BIM technology will certainly demonstrate its capabilities and provide strong support in the design-to-cost field, with its advantages becoming clearly evident in the coming years.

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Research on Engineering Cost Control based on BIM Technology

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Abstract: At present, based on 2D drawings, the project budget usually gets final data through model reconstruction, summary and calculation. The project budget often begins from the stage of drawings and engineering design decisions often ignore the economic rationality. This article aims to find out the mode to connect BIM model with the common cost software, to realize that designers can participate in cost control, to eliminate the work of building model for engineering cost calculation, to improve work efficiency, and meanwhile to explore the rich information of BIM model.

Key Words: Design-Cost model; Modeling Standards; Cost Control

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